INFORMATION FOR DECISION MAKING

PRENTICE-HALL., Englewood Cliffs, New Jersey

INFORMATION FOR

EDITED BY
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DECISION MAKING:
Quantitative and Behavioral Dimensions

658.501
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13-464370-4
Library of Congress Catalog Card Number 75-99432

Current printing (last digit)
10 9 8 7 6 5 4 3 2 1

PRENTICE-HALL INTERNATIONAL, INC., *London*
PRENTICE-HALL OF AUSTRALIA PTY. LTD., *Sydney*
PRENTICE-HALL OF CANADA, LTD., *Toronto*
PRENTICE-HALL OF INDIA PRIVATE LTD., *New Delhi*
PRENTICE-HALL OF JAPAN, INC., *Tokyo*

Printed in the United States of America

Preface

The subject matter of this book may be characterized by such contemporary labels as "management information systems," "management accounting," and "management decision making." More specifically, this book is addressed to the informational aspects of management systems. Information, that is, data organized to be useful for decision making, is essential to the survival of all goal-oriented organizations. Recent developments in information technology, quantitative methods, and the behavioral sciences have greatly expanded the potential of information for organizational decision making. Where once the financial accounting model served as *the* formal information system, we are now witnessing the emergence of management information systems emphasizing mathematical models, systems philosophy, *ex ante* measures, and nonfinancial as well as financial measures. Thus the primary objective of this text is to relate these advances in the management sciences, including the behavioral sciences, to the task of effectively designing and using decision-oriented information systems.

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To facilitate this objective the articles have been carefully selected after an extensive search of the literature on the basis of relevance and clarity of exposition. Because the emphasis throughout the book is on concepts rather than techniques, students with only modest training in quantitative methods should be able to read the selections with relative ease and comprehension. As a further aid to the reader, a summary highlighting salient points precedes each selection.

Editorial comment is offered at the conclusion of each chapter. The purpose of these editorial comments is to stimulate discussions. Thus, depending upon the nature of the article, the comments generally focus on some or all of the following points: (a) key assumptions inherent in the proposed model; (b) advantages and limitations of the model; (c) problems of implementation; and (d) possible extensions of the model. Understandably, certain selections warrant more discussion than others. For example, more editorial commentary was devoted to the provocative and controversial article by Ackoff. In the interest of a more comprehensive discussion, references to other relevant literature are often included in the editorial commentary. For student research projects or readers who wish to do further study, bibliographies appear at the end of Part One and Part Three and also at the conclusion of each chapter in Part Two.

The book is divided into three parts: Background and Approach, Information for Planning and Control, and Behavioral Aspects of Information. Part One is primarily devoted to sketching basic philosophies relating to information systems, models, and decision making. The role of models in decision-oriented information systems is emphasized. Part Two begins with a framework for viewing planning and control systems and is followed by an analysis of the informational aspects of various types of planning and control models. Finally, in Part Three the impact of information on decisions and organizational performance is examined. The main plea in this section is that designers of information systems must consider not only the problem the user is trying to solve and the data required to solve it, but must also consider how the manner and form of the data to be communicated may affect his behavior.

I express my thanks to the authors and copyright holders of the selections included in this book. While the candid editorial comments indicate my disagreement with a number of points offered by the contributing authors, I wish to underscore my acknowledgment of their important contributions to the literature. Special thanks are due to Professor Rene P. Manes, Purdue University, for his helpful suggestions on the editorial comments. For cheerful typing assistance, I am indebted to Mrs. Edith A. Bass and Miss Joan Walla. K. V. Ramanathan, a doctoral candidate at Northwestern, assisted in the laborious but essential task of proofreading the manuscript.

Alfred Rappaport

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INFORMATION FOR DECISION MAKING

Part I

BACKGROUND AND APPROACH

1

A Setting for Information and Decisions

THE STRUCTURE OF MANAGEMENT DECISION THEORY

Stephen H. Archer

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One acting in the capacity of a manager or an executive must make choices among various plans, policies, and strategies. Among other conditions, decisions must be made under varying degrees of information—customarily classified as conditions of certainty, risk, and uncertainty. Decision theory attempts to give structure and rationale to the different conditions under which decisions are made. A great many problems or gaps still exist in the theory. This article provides a review of some of the essential elements of management decision theory and a commentary on some of the problem areas where continuing attention might profitably be focused.

Managerial Activity

A considerable amount of managerial activity customarily precedes the actual decision. In large organizations these activities may be carried on in the management structure, or at least in part, by people other than the official decision-maker. Staff people and others in the line organization discover problems, define them, and prepare the alternatives for decision. The decision is only the conclusion of some process. The process in a broad sense includes:

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(1) the activities of discovering and defining things to decide about; (2) determining the objective of the organization; and, (3) the enumeration and preparation of the alternative ways of making a decision.

After the preparation of alternative plans or strategies, the payoff of each strategy has to be determined. The information required to determine the payoff is secured only at some cost. Management has the difficult task of deciding when the costs of securing additional information are warranted by the nature of the problem (another decision in itself). At some point, the costs of securing additional information are not warranted and the decision-maker must make decisions in the face of some uncertainties.

A manager *must* choose among alternative strategies. Failure of the manager to make a choice will cause certain malfunctioning in the organizational activity; the importance of the decision abstention is dependent upon the significance and nature of the particular managerial "component" in the structure.

The manager elects one strategy over others based on criteria such as minimum cost, greatest rate of return, maximum sales, or some combination of criteria or objectives. A goal or a mix of goals exists that he is striving to attain. The goals are probably not completely personal goals, for his personal objectives become reshaped and modified subject to the pressures of stockholders, employees, other managers, and so on. In the organization, the mix of specific goals that maximizes his utility includes, among other considerations, achieving what he believes others feel should be the organizational goals. If his beliefs as to the organizational goals deviate too far from the beliefs of others, his selection of strategies will be criticized. The manager compares the various strategies to find the one (or a mix of several) that comes closest to the attainment of his goal(s); that is, he optimizes.

The mix of specific objectives of the individual are, in effect, only one in his mind—his satisfaction or his utility. The goal of good health, for example, must be weighed by an individual against the goal of respect of his work partners which might be gained by industriousness and achievement. The goal of health restricts complete concentration on the "respect" goal and thus a lesser attainment of this goal is accepted. The resultant compromise of these specific goals is the ultimate single goal of personal maximum utility —one goal. If one can accept the decision-maker's one goal of maximum utility, the difficulty of dealing with the problem of "dimensionality" (many dimensions) of goals disappears.[1]

Components of the Decision Matrix

It is obvious that an outcome of a decision must occur after the decision is made. The time between a decision and its final outcome may vary considerably depending upon the type of decision and the accuracy desired in the measurement of the outcome.

Outcome Measurement

Some outcomes may not be fully measured even in centuries. On the other hand, many outcomes are measurable for practical purposes, within a reasonably short time after the decision has been made. In some cases this time elapse is very short, perhaps less than

[1] David W. Miller and Martin K. Starr, *Executive Decisions and Operations Research* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960), p. 68.

a second. For example, the decision to turn a door knob to the left instead of the right will produce an outcome which is known within a very brief period after the decision is made. The decision of a country, on the other hand, to join the European Common Market may produce an outcome that likely would not be known for many years or perhaps centuries in the future.

Rather than waiting indefinitely to measure the outcome of some decision, it is customary to establish an arbitrary cutoff time—say, ten years, in the case of the Common Market. During this period, most of the direct effects of the outcome should have occurred. Nevertheless, some amount of time must pass before an outcome is determined, and the payoff or measured outcome is a function of the length of the measurement period. The payoff predicted depends upon the arbitrary cutoff time selected and the danger of selecting the wrong strategy will be less if the predicted payoffs reflect the more complete impact of the strategy.

Strategies

The alternatives available in any decision problem are referred to as "strategies." The number of strategies to choose from may vary from two to infinity (if there were only one, there would be no decision). The decision alternatives in the case of opening a door were to turn the door knob to the left or to the right, and this involved only two alternatives. The decision to select a text for a particular class may involve numerous, but a finite number of, alternatives. If, however, one were producing ale, the quantity of water to add to the mix may include alternatives of ten gallons, one gallon, and one millionth of a gallon. Although these seem to be a finite number of alternatives, the alternatives are really infinite; the inaccuracy of the measurement system prevents one from measuring infinitesimal quantities or differences in volumes of water that might be added.

In most operating circumstances, however, all possible alternatives are not enumerated or considered, but only a limited range of alternatives. The range may still leave an infinite number from which to select, as in the ale example. But there are enough rules of good beer-making to establish that the water added ought to be within the range of, say, 8 to 8½ gallons to a ten-gallon barrel. This still leaves an infinite number of points between 8 and 8½ gallons, but one might decide to structure the alternatives in only tenths of gallons. In the choice of a textbook, certain rules are also likely to act to circumscribe the number of alternatives which a decision-maker must face. For example, the rules might be that no text more than ten years old will be considered; no text will be considered that was not produced by a publisher of college texts; no text will be considered which is not relevant to the nature of the course being given (some objective measure of relevancy).

Strategies are sometimes innumerable and must be described as an infinite number within a certain range. There are certain techniques for eliminating strategies from further consideration—those which are known not to be considered as successful in achieving the objectives. The elimination of certain strategies from the group to be considered is accomplished using the information of the person enumerating the strategies. He predicts, based upon his knowledge and experience (reflected in the form of "rules" for action), that these strategies could not result in outcomes as satisfactory as those remaining to be considered. The techniques for restricting the number of strategies available may be fairly crude and im-

perfect. They are practical. It is certainly possible that some of the strategies eliminated might be desirable but, in effect, the person restricting or enumerating strategies considers the probability of their satisfactory payoff to be so extremely small as not to be worth the cost involved in further consideration.

This problem of deciding how many strategies to present to the decision-maker and the risks of error involved in elimination of strategies are very important problems in decision theory.

A rather formalized procedure has been used in some cases for reducing the number of alternatives to be considered. This procedure, referred to as "heuristic programming" consists of successive applications of rules (usually with the aid of a computer) deemed to be appropriate, so that the number of alternatives is reduced to sufficiently few as to be manageable by the decision-maker. If the rules are sufficient, the number of strategies can be reduced to one, thereby eliminating the decision problem. The models of ways of arriving at a decision under the various conditions that follow in this paper are nothing more than rules to reduce alternative strategies to one—the optimal. Decision theory becomes a case of heuristic programming in a broad sense.

In other cases, the problem of operating management is not to restrict the number of alternatives to a manageable number, but more to be aware of a sufficient range of alternatives. Management may at times benefit by simply attempting to enumerate alternative strategies rather than choosing among only the few traditionally used strategies.

Payoffs

The selection of any one strategy will result in a payoff or outcome. If we were fortunate enough to know the payoff associated with each strategy, we would be able then to simply select the strategy with the largest payoff, assuming maximization. The determination of such a payoff requires a complete understanding of the manner in which the decision and its resultant activities yield a particular payoff. This situation of being able to predict the payoff with certainty would be very unusual for most business situations.

Frequently our prediction is less than perfect; that is, the situation is not one of certainty. Our predictions of payoff are dealt with by such conditional phrases as "assuming certain conditions" or "depending upon the state of the economy" or similar expressions illustrating the lack of complete understanding of the operation of the system with which we are involved. There are so many variables about which we know so little that in most cases we cannot predict the payoff that results from the interaction of these unknown variables with the activities undertaken as a result of the decision. Customarily we know of only a few of the variables that affect the outcome and have less than perfect knowledge of their influence on the outcome. Therefore, the outcome or payoff is predicted with less than complete certainty.

Conditions

More recently, popular decision theory has reduced or eliminated the model constraint of certainty or one state of nature in dealing with decision problems. This permits us to predict outcomes that depend upon particular "states of nature" or conditions that occur.

Under this model, it is not necessary to know what causes these conditions to occur, but it is desirable to know the approximate relative frequency

with which these different conditions are expected to occur. (However, knowledge of the causes of the occurrence of these states may be very useful in determining their expected relative frequency.) If we can present the relative frequency of the states of nature by some probability distribution, we may then concentrate our efforts on the problem of determining the payoff given a certain state of nature. Presumably, the state of nature describes the conditions within which the activities set in motion by the decision operate.

The conditions or states of nature include the states of variables over which control is limited or nonexistent, many of which might be termed environmental variables, as well as others. A state of nature, for example, in a particular problem might refer to the state of the economy, weather conditions, inventory levels, and so forth. The assumption in this type of model is that after the state of nature has been described, the payoff resulting from the selection of a particular strategy can be precisely determined (or approximated in the sense that measurement systems in practice are limited).

An example of an elementary enumeration of strategies, states of nature, and associated payoffs is presented in matrix (tabular) form below.

	States of Nature (N)		
Strategies(s)	N_1	N_2	N_3
S_1	P_{11}	P_{12}	P_{13}
S_2	P_{21}	P_{22}	P_{23}
S_3	P_{31}	P_{32}	P_{33}

The strategies are enumerated in the rows and the states of nature in the columns. The payoff associated with a state and the choice of a strategy is given in the body of the table.

In actuality, determination of the payoff, given the state of nature, is not likely to be precise, nor will the enumerations of strategies or states of nature be complete. However, the model exists; the degree of refinement depends upon the particular problem involved and the reliability which one desires to achieve. In most business problems, the payoffs, given certain states of nature, are not completely deterministic, but at least the estimates of the payoffs are more accurate (or should be more accurate) than under the assumption of no variability in the state of nature at all (the certainty model).

States of Nature

The different conditions under which payoffs are determined bear some further consideration and inspection.

Certainty

Under conditions of certainty, the payoff resulting from the selection of a particular strategy is known. It is assumed that the payoff resulting from the decision can be precisely measured; in other words, only one state of nature is assumed to exist. Prediction is involved, but prediction is assumed to be perfect. A substantial amount of knowledge and understanding of the working and behavior of the system is required in order to exert enough control to be able to assume a state of certainty. In probability terms, the probability that a certain state of nature exists is assumed to be one. The assumption of certainty simplifies the decision but ignores variations in conditions which often exist, leading to improper decisions.

For example, our strategies might be the selection of various inventory levels to attain on January 1 of the coming

year; the payoffs in this case are stated in terms of profits.

Strategies: Inventory levels	*State of Nature*
200	$ 50
250	300
300	500
350	200

In this case, the enumeration of strategies has been limited by prior decision and knowledge, to the range of 200 units to 350 units. Additional refinement which might be desired would require more choices than the four presented here—perhaps all discrete integer values between 199 and 351. If, however, the profit distribution (payoffs) is known to be unimodal, we could further restrict the range of strategies to those near the 300 unit level. If at 301, profits were greater than at the 300 level, we should proceed to investigate the payoffs in this direction until they begin to decrease. If the profits were a continuous function of the inventory level, the maximum value could be simply obtained by differential calculus.

The profits in this model are predicted. The use of this model for decision assumes these are predicted perfectly or with insignificant risk of significant error. If we can associate with certainty the profits that would result at some measurable time in the future for each inventory level or strategy, it is a model under certainty. Realistically, however, one cannot rely on these profit levels being obtained, given only information on inventory levels. Many other known and unknown factors influence the level of profits. In business decision, a state of certainty is the exception.

Risk

If the decision model does not assume certainty but assumes risk, the various states of nature can be enumerated, and the long-run relative frequency of their occurrence is assumed to be known. For example, it is known that a combination of seven appearing in a roll of a pair of dice will occur in the long run with a relative frequency of 6/36. If eleven states of nature occur in the long run exactly as do the roll of two dice, probabilities can be assigned the eleven states. In other cases, the probability distribution may take on a continuous form such as a normal distribution. In this model, we assume we are certain about the relative frequency with which the given states of nature will occur in the long run. We do not assume any one state, but many; we do however assume that we know the probability of the occurrence of the various states.

There exists in this model more than one payoff for each of the strategies prior to the decision. After the decision has been made, obviously only one of the payoffs can occur as a result of the decision. A payoff exists for each combination of strategy and state of nature. In the table below there are three outcomes associated with each strategy.

States of Nature and Their Respective Probability of Occurrence

	States of Nature		
Strategies	*A(.25)*	*B(.50)*	*C(.25)*
1	P_{11}	P_{12}	P_{13}
2	P_{21}	P_{22}	P_{23}
3	P_{31}	P_{32}	P_{33}
4	P_{41}	P_{42}	P_{43}

If we were given a state of nature as having occurred and the selection of a particular strategy, the payoff would be assumed to be known with prefect precision, which in the actual case is seldom true. However, in any one decision, we do not know which of the states of nature will occur but only

have expectations as to their relative occurrence.

A considerable amount of care needs to be exercised in assuming the risk model. The probability distribution of the states of nature is assumed to be known. Decision theory requires that the risk model should be used only when this is the case, although this assumption is frequently overlooked.

The number of states sufficient to use the risk model with confidence is a subject deserving further discussion and development. As with the certainty model, the prediction of the payoffs in the matrix is assumed to be perfect. In some circumstances, when certainty assumes one state of nature and the payoffs cannot be accurately predicted, a change to a risk model which permits specification of different conditions produces more accurate payoff predictions. The number of states of nature should be sufficient to provide accurate payoff predictions.

It should be emphasized that, if the risk model is to be used properly and lead to the correct decisions, the time in which the outcome as a payoff is to be determined must be sufficient to encompass all of the results of the decision. In the interest of reasonableness of operation, it is desirable to establish some cutoff point for measurement purposes. It is within this period that we seek perfect prediction of the payoffs. Part of the outcome beyond this point is ignored, but should not be of significant importance if the cutoff time is appropriately established.

Uncertainty

Uncertainty exists when one does not know the long-term relative frequency with which the states of nature will occur.

1. Based upon past objective experience, one may be *relatively* confident of the nature of the probability distribution of states of nature.
2. Based upon one's judgment, one may estimate the probability distribution.
3. One may guess at the probability distribution of the states of nature based upon his subjective impressions.
4. Or there exists no information whatsoever as to the relative frequency with which the states of nature will occur.

Uncertainty in decision theory describes all shades of knowledge of the probability distribution of the states of nature ranging from near accurate estimates based upon objective experience to an extreme case in which no knowledge exists. It is this type of model which most frequently applies to management decision. Uncertainty varies from the extreme of no information up to but excluding the condition of risk in which the probability distribution of the states of nature is known. Short of risk conditions, exists uncertainty.

Decisions under Risk

In the certainty decision model, the decision between alternative strategies is relatively obvious—namely, *select the strategy whose payoff is largest or smallest depending upon whether the decision-maker is maximizing or minimizing*. In the case of risk, the decision is not so obvious.

Expected Value

Under conditions of risk, the decision-maker must review the payoff matrix (his knowledge of the various payoffs), which represents combinations of states of nature with their probabilities of occurrence and strategies, in order to arrive at a decision. At first glance, one might be inclined simply to average the payoffs for each strategy, but this does not give proper weight to the relative frequency with which the

payoffs are expected to occur. The payoff should be weighed by the probabilities involved. As the probabilities themselves add to one, it is not necessary to divide the weighted sum by any factor. The "expected value" of a strategy is the sum of the payoffs, each multiplied by its respective probability of occurrence. An expected value may be derived for each strategy.

The appropriate decision is to select the strategy with *optimizing expected value* (largest, for maximization of the payoff unit).

	States of Nature			
Strategies: Inventory levels	*A(.25)*	*B(.50)*	*C(.25)*	*Expected Values*
200	100	100	50	87.5
250	90	120	100	107.5
300	70	120	140	105.0
350	40	90	190	102.5
400	0	50	160	65.0

In this example, the payoffs are profits which the decision-maker wishes to maximize. The optimal strategy is therefore the stocking of 250 units, for the expected value (the average profits from such a decision in the long run) is higher ($107.5) than for any other strategy.

However, if the probability distribution were uniform (the probabilities of the states of nature were known to be equal), the optimal choice is to stock 350 units.

The expected values in the table are the weighted averages for each of the strategies. A solution to this decision problem was to select that strategy with the highest expected value. This is the most common decision-making criterion under the condition of risk. It will produce satisfactory results in many cases.

Consider, however, the decision between two alternative strategies one of which will give a payoff of 8 million dollars with a probability of 1 and the other strategy, a payoff of 10 million dollars with a probability of .9 and a loss payoff of minus 10 million dollars with a probability of .1. The expected value in each case is 8 million, and thus, under the expected value criterion, each strategy would be equally desirable. Upon introspection, however, the preferred strategy is that leading to payoff of 8 million dollars with certainty rather than the one with a possible loss of 10 million dollars, even though the probability of occurrence is relatively small, particularly when the event is a one-shot affair. It may appear that the expected value method in this

	States of Nature			
Strategies: Inventory levels	*A*(⅓)	*B*(⅓)	*C*(⅓)	*Expected Values*
200	100	100	50	83⅓
250	90	120	100	103⅓
300	70	105	140	105
350	40	90	190	106⅔
400	0	50	160	70

particular example is less than satisfactory. The criticism levied against expected value (as implied) as a criterion is not a proper criticism of the technique of taking weighted averages of the payoffs; the fault lies in the manner of expressing payoffs in the traditional form such as profits or sales.

The issue is one of payoff measurement rather than one of expected value. Even though the payoffs may be quantifiable, they may not have been measured in terms of the values we wish to optimize. If one is seeking to maximize utility (via some mix of goals), profit may, in many situations, be an inadequate measurement of utility. Frequently, one may indicate that he is not interested in profits but survival of the firm, survival of the managers in their present positions, and so on. However, one usually proceeds to state the firm shall be assumed to be maximizing profits. Upon observing the results of decisions based upon profit maximization, some complain our techniques of decision-making are inadequate. The criterion used—profit maximization—simply ignores other aspects of utility, primarily variability of the returns. Doubling profits will not likely double utility. To arrive at the proper strategy necessitates converting the payoffs to relative utilities from which we may then compute the expected values. The best strategy is that with the maximum expected utility or minimum disutility.

In the example above, the payoff of minus 10 million, in utility terms, would be given a greater weight in the averaging process due to the disutility, and, consequently, the expected value computed would be less than the expected value of the certainty alternative.

The reader may tend to back away from utility considerations because of the near-universally-accepted criticism of any type of utility measurement. At least theoretically, utility cannot be ignored, for it is maximum satisfaction which is the real objective of the manager. If we assume we are dealing with only one manager, and we are interested only in one mental decision process, we are not forced into the argument of the lack of comparability of utilities between two individuals. For any one individual, one may state that a payoff to an individual may be less or greater than another payoff to him in terms of utility. That is, one ought to be able to rank the payoffs in terms of satisfaction to him as a manager.

Ranking, however, is not completely satisfactory, for it tends to ignore degrees of preference which a manager may have for one payoff over another. The payoffs can be converted to relative utilities by a technique referred to as "standard gamble" method[2] which may be used to assign payoffs to positions on a utility scale from zero to one with reasonable reliability, if properly used.

Let us assume a particular strategy will result in the occurrence of three possible payoffs, *a*, *b*, and *c*. Although the technique does *not* require that the payoff be in dollars of profit, let us assign a gain of $0 to *a*, $100 to *b*, and $200 to *c*. Without knowing anything at this point about the relative frequency or probability of occurrence of *a*, *b*, or *c*, let us set down their utility to the decision-maker. We can rank these on any relative scale such as 0 to 10, 0 to 1,000,000, or 0 to 1; let us choose the latter. We know *a* is the least desirable to the decision-maker, so we assign it a relative value of 0. We know that *c* is the most desirable, so we assign it a value of 1; *b* should have some intermediate value. For each

[2] John Von Neumann and Oskar Morgenstern, *Theory of Games and Economic Behavior* (Princeton, N.J.: Princeton University Press, 1947). See also *ibid.*, pp. 69–72.

intermediate outcome, determine when a decision-maker is indifferent to (1) receiving that outcome for certain and (2) a lottery between the extreme values with an assigned probability. For example, a decision-maker is offered the choice between (1) b for certain and (2) a result with probability p of getting c and a 1-p chance of getting a. If p is equal to 1, then he would choose alternative (2). If p were 0, he would choose alternative (1) and take the $100. At some p between 0 and 1, he would be indifferent to (1) and (2). If we assume his particular utility pattern causes him to choose p equal to .8, we have thus assigned relative weights (0, .8 and 1) to the outcomes a, b, and c—a scale of relative utilities of the payoffs.

Indifference Curves

Another method for solving the decision-making problem may be used. This one is similar to the expected value method when used with utility payoffs. As before, each strategy that may be chosen has a distribution of possible payoffs. The specific payoff that will occur depends upon the actual state of nature that does in fact occur. We have, before the decision is made, information only on the expected relative occurrence of these states and, therefore, the expected relative frequency of the payoffs associated with each strategy.

The average payoff is nothing more than the expected value—computed as a weighted average of the payoffs for each strategy. As before, one is inclined to select the strategy with the largest return, in the case of, say, profits. This result may lead to unsatisfactory decisions as indicated in the discussion of expected value criteria using nonutility payoffs. One may, however, increase the dimensions of the evaluation of strategies and study each strategy not only with respect to average payoff but also with respect to the variability of expected returns *and* their expected variance.

The problem facing the decision-maker is to choose a strategy giving a combination for expected payoff and variance which is optimal, giving him the greatest satisfaction. He may enumerate all the strategies and observe the expected returns and the expected variability involved for each of them. Markowitz developed a technique for dealing with combinations of variance and returns in investment portfolio analysis.[3] He indicated that "efficient" strategies or portfolios (combinations of securities) are a subset of all strategies. Nonefficient strategies may be immediately eliminated as the manager chooses portfolios or strategies such that: (1) among strategies of equal variability, he would select the one yielding the greatest expected payoff and (2) among strategies with the same expected payoff, the manager would prefer the one with the smallest variance. All the remaining strategies can be approximately represented by a curve (assuming continuity) of strategies constituting a set of efficient strategies. Without going into subtle explanations here, such a curve would have an appearance similar to the curve in Figure 1.

At high levels of expected return, a decision-maker would be willing to accept greater variance. Consequently, the curve is upward sloping to the right. It reflects combinations of variance and average returns which must be superior to all other possible combinations. Each point along the curve represents a single strategy—a single combination of average payoff and the variability of payoffs.

[3] Harry M. Markowitz, *Portfolio Selection* (New York: John Wiley & Sons, Inc., 1959).

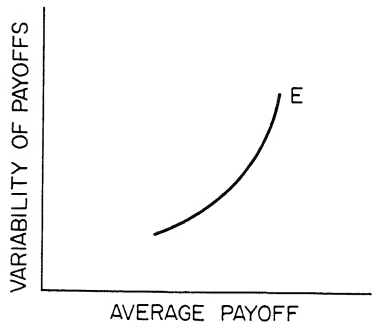


Figure 1

Given the set of strategies all of which are efficient, which strategy should the manager choose? Which combination of return and variance is optimal in terms of his satisfaction? How much of the greater variance is the manager willing to bear in order to receive a greater return?

A device for summarizing the manager's attitude toward these combinations may be constructed and is commonly known as the indifference curve. As the curve reflects the manager's attitude to the average payoffs versus the variability of payoffs, it performs a function similar to the transference of standard payoffs into utility terms. It evaluates *two* dimensions of each strategy, the average and the variance payoffs; whereas the utility payoff measurement permits inclusion of any number of dimensions. This is an advantage only if more than two dimensions are felt necessary to evaluate the strategies.

The family of indifference curves can be drawn or constructed. At all points (strategies) along any indifference curve, the manager is indifferent to the choice of one strategy (combination of risk and payoff) over another. Figure 2 illustrates a family of indifference curves. One can construct an almost infinite number of indifference curves for the individual manager. They slope upward, reflecting the manager's liking for payoff and his dislike of risk; the curve is more likely to become flatter as it rises; to induce him to take on greater variability, he must be compensated with a greater return. Each indifference curve represents a set of strategies to which the manager is indifferent. A strategy is a point in two-dimensional space; not all of these are feasible or even available. Only those on the "E curve" are feasible strategies, from which the manager must choose one.

The manager's decision would be to select the strategy at the point of tangency of one of the indifference curves and the efficiency-strategy curve as shown in Figure 3. At the tangent point S_1, the optimal strategy is obtained—the combination of average payoff and

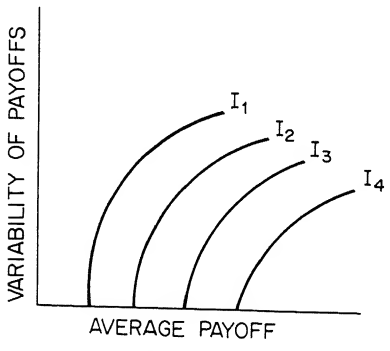


Figure 2

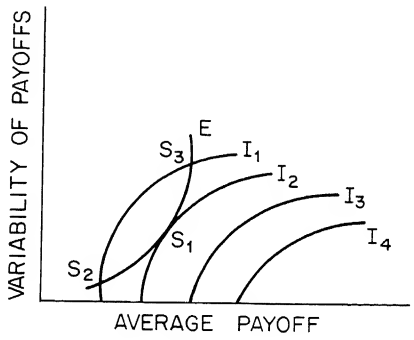


Figure 3

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variance which is optimal for this manager. Other points along this curve I_2 and curve I_3 do not include any of the feasible strategies along its line, including S_2 and S_3. All points between S_2 and S_3 are inefficient; that is, other strategies exist which provide higher returns with the same variability or lower variability with the same returns. Points S_2 and S_3 are efficient but lie on an indifference curve yielding a lower level of satisfaction.[4] This technique of the indifference curves, in effect, has built utility into the system. The individual manager in this curve reflects his likes and dislikes for risk and return.

The measure of dispersion or variability about the average payoff is customarily referred to as the "risk" associated with the selection of the particular strategy. Risk of the variability of the payoffs may be identified, in the use of this technique, as something less than the complete probability distribution itself. A convenient measure of risk may be used which measures only the dispersion of the distribution of payoffs. A satisfactory measure of dispersion for most cases is a form of the standard deviation. The standard deviation is usually expressed in absolute quantities. It is desirable, in order to make comparisons of levels of risk, to measure these standard deviations on a comparable basis relative to the mean of the distribution. Consequently we introduce the coefficient of variation, which is defined as the standard deviation divided by the mean. This one value represents the relative dispersion of the distribution about the mean, representative of the risk involved in a particular strategy.

The problem of expressing risk in quantitative terms is one which has not been fully solved. The coefficient of variation is sometimes criticized as not satisfactorily expressing the risk involved. Some critics argue that the absolute standard deviation of two expected payoffs of, say, five, and the same absolute standard of an expected payoff of, say, ten, would involve the same risk even if the mean were higher in the second case. The probability distribution has the same absolute standard deviation but is based on a different mean.

On the other hand, for equal risks, one may inquire whether, due to the higher mean, we should require a proportionally higher standard deviation. If one does accept a proportionally higher standard deviation at a higher mean, he should prefer the coefficient of variation—a relative measure of risk.

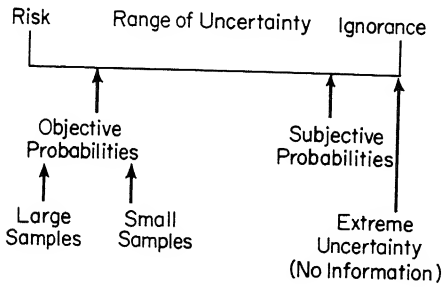
Another concept for the measurement of risk is one used in information theory: that of "entropy," which has certain properties of advantage in measuring risk. In this case, the shape of the distribution need not be assumed to be the same as it is in standard deviation. Entropy measure uses all values of the probability distribution and will have a low value for a uniform distribution and will have a higher value for a more concentrated distribution. A possible difficulty with the use of entropy as a measure of risk is that it will give different values depending upon the number of possible outcomes enumerated (in the case of the discrete distribution). If the outcomes were ten in one case and five in another, different values of entropy would be obtained even though the range of dispersion might be the same. However, for most decision problems, the number of outcomes for each strategy could be stated

[4] William S. Sharpe of the University of Washington has applied this type of analysis to capital allocation models for the firm in S. H. Archer and C. A. D'Ambrosio, eds., *The Theory of Business Finance: A Book of Readings* (New York: The Macmillan Company, 1967).

as the same, even if it meant assigning zero probabilities to those outcomes.

Decision under Uncertainty

Decision under *uncertainty involves a range of conditions* in which the probability distribution of states of nature varies from one in which we have considerable confidence, based upon objective experience, to the other extreme—conditions of uncertainty on which we have no information concerning the relative frequency with which the states of nature will occur. We shall look at uncertainty models at a few points along this continuum.



Objectively Obtained Probabilities

Under this class of decision problems, the selection of a particular strategy is based upon probabilities of the states of nature that are expected to occur; the probabilities in this case are estimated by use of objectively obtained experience. The relative frequency of the occurrence of the states of nature in the past has been accumulated; however the amount of experience recorded usually varies from a small amount of experience to considerable experience.

The information secured about the probability distribution may have been obtained through the accumulation of data on past experience or may be obtained, as it is in many cases, through a current investigation such as that based on sampling techniques. (There is a strong inclination to digress into the area of statistics at this point; however, in the interest of progress in our main topic, we shall avoid this diversion.)

In any case, the confidence that a decision-maker has in the probability distribution depends upon the number of observations which has been accumulated either from experience or by sampling. The acceptability of the accumulation of past experience, on which to base estimates of the relative frequencies of occurrence in the future, depends on the belief that the process under study is stable over time. This assumption, of course, is also necessary in the acceptance of the inference about future probability distributions based on a sample result. Statisticians tell us that uncertainty decreases as the size of the sample or experience increases; that is, the likelihood of error in the distribution will decrease as the number of observations increases. We may use as the distribution for the decision problem the relative frequencies as they were accumulated, or we may fit a distribution (binomial, normal, Poisson, etc.) to the data, particularly if we have enough knowledge of the events and how they occur to know the shape of the actual population about which we are making inferences. Presumably, as the sample was taken by scientific (systematized and unbiased) procedures, we may measure the error involved in estimating the parameters of a particular probability distribution, a problem of statistical estimation

The decision procedure for this type of model is similar to others. After the probability distribution has been decided, one may compute the expected value of utility payoff or the risk in the case of indifference curve analysis. The decision procedures are the same as

they were under risk, when we knew the "population" probability distribution.

There is, however, a difference in this case. The probability distribution used may not be the same as the "population" distribution due to sampling error. The probable range of error and the impact upon the decision *may* be determined.[5]

Subjective Probabilities

The second class of decisions under uncertainty involves those where the decision-maker has no objective experience on which to rely, but on which he will desire to act on the basis of his best judgment. His judgment is based on past experience in the form of observations, but the observations are not scientificially obtained. His statements are subjective. Schlaifer and others have suggested that the decision-maker, even though relying on judgment, ought to formalize his decision process by constructing a subjective probability distribution.[6] The subjective probabilities can be estimated by the decision-maker using his best judgment as to the relative frequency with which the states of nature would be expected to occur. The internal consistency of these probability estimates can be improved through the use of a lottery procedure similar to the standard gamble procedure.[7]

Given a subjective probability distribution of different states of nature, the selection of a particular strategy may be carried out as before, namely, through the use of expected value of the utilities of outcomes or the indifference curve analysis.

[5] See R. Schlaifer, *Introduction to Statistics for Business Decisions* (New York: McGraw-Hill Book Company, 1961), Chaps. 10, 11, 17, 18.

[6] *Ibid.*, pp. 13–22.

[7] *Ibid.*, pp. 13–14.

The use of the subjective probability distribution in decision-making, however, cannot be assumed to have the same attributes as the objectively secured distribution. The objective distribution permitted us in many cases to estimate objectively the possible errors involved in relying on it. However the subjective distribution suffers from the lack of that attribute. Different individuals will likely express different distributions for the same problem and each will likely have varying degrees of confidence in the distribution.

It would be desirable to develop a technique to approximate our confidence or credibility in subjective distributions. It would also be useful to establish methods of combining judgments of distributions of different individuals so as to increase the confidence or reliability in the estimate of the distribution.

A recent exercise by a graduate student compared the results of combining subjective distributions of many individuals in order to observe the behavior in the estimate of population values. It was necessary to select something about which those sampled could give reasonable subjective impressions and for which actual population values were available. These were also compared to random samples from the population taken objectively via a random number table. The pooled percentages for each class of the student-age distribution compared with the objective sample results, for a sample of size 50, is shown in the table opposite.[8]

[8] L. E. Richards, "A Study of Pooled Subjective Distributions Toward Approximation of the Objective Distributions" (unpublished research report, University of Washington, 1963), p. 48. Fifty students (random sample) were asked what they believed was the age distribution of all students on campus. The proportions they estimated for each class were then averaged (pooled). In the objective case, 50 students'

Subjective, Objective, and Population Proportions

Age Class	*Subjective Pooled Values*	*Objective Sample Values*	*Population, True Values*
15 through 17	4.4%	0.1%	0.6%
18 through 20	40.8	36.0	41.0
21 through 23	24.1	42.0	26.6
24 through 26	13.9	10.0	13.2
27 through 29	7.3	8.0	7.1
30 through 34	4.4	2.0	5.9
35 through 39	2.6	2.0	2.7
40 and over	2.4	0.0	3.0

The subjective distribution improved as an estimate of population values as the size of the sample increased from ten to fifty. A similar exercise was completed for the distribution of automobile manufacturers and bore out substantially the same results.

Other advances have been toward methodology for combining subjective and objective data. When objective data are limited, how much weight should be assigned the subjective distribution(s)? Bayesian analysis has suggested the application of objective experience to subjective prior distributions in order to arrive at revised, posterior distributions.[9] If a sample of only one can be secured, the subjective distribution will have a strong influence on the posterior probabilities. As successive observations are added, the influence of the subjective distribution decreases. If only one observation can be secured, however, it would be desirable to differentiate between a subjective distribution in which we have considerable confidence and one in which we have little credence.

A solution to the problem of evaluating confidence in subjective distributions would help us both in combining subjective information and in combining objective and subjective information. It would also help in determining the point at which sufficient objective data permit us to ignore the subjective information. Sufficient sequential sampling will, in any case, eventually almost entirely eliminate the influence of the original subjective prior distribution.

At some point, the lack of confidence in the subjective distribution, if no objective data can be obtained, warrants dropping the idea of using any of the above models. In such cases, the decision-maker assumes complete ignorance and must turn to models of decision-making under extreme uncertainty.

Decisions under Extreme Uncertainty

In this class of decision problems, the decision-maker is assumed to have no information available to him about the relative frequency of occurrence of the various states of nature; he does not even have subjective judgments concerning such probability distribution. In these cases, it would be hopeless to attempt to assign any such probabilities to the states of nature. An attempt to place the decision process in such a framework may result in a poorer decision than with other assumptions such as ignorance about the probability of the states of nature.

ages were randomly selected and placed in the age classes. Both of these estimates were then compared with the registrar's figures on ages of enrolled students.

[9] Schlaifer, *op. cit.*, Chaps. 12, 13.

The criteria offered for use in arriving at a decision under extreme uncertainty are many and include such descriptive titles as rationality, pessimism, optimism, regret, and surprise. All of these have been suggested in the literature. Rationality, for instance, assumes that the decision-maker has no idea as to the relevant probability assignments, and, due to insufficient reason, it is assumed that all states are equally likely to occur. Equal probabilities to all states of nature are assigned and in this case the simple expected value (equivalent to an unweighted average of payoffs) is computed and the decision-maker simply selects the strategy with the highest expected payoff. This criterion of rationality has also been referred to in the literature as "the criterion of insufficient reason or the Laplace criterion."

Another criterion, suggested by Abraham Wald and others, is based upon a pessimistic outlook by the decision-maker who then chooses the strategy with the maximum of all minimum returns. An opposite rule, the optimistic criterion, selects the maximax criterion, in which case the decision-maker selects the strategy with the maximum of the maximums. Hurwicz has constructed and presented yet another criterion which takes into consideration the decision-makers' varying degrees of optimism in their views on particular decisions.[10]

Another criterion, introduced by Savage, is called the criterion of regret; the decision-maker is assumed to minimize regret.[11] Regret is measured as the difference between an actual and the expected payoffs.

A potential surprise function was presented by G. L. S. Shackle for his criterion.[12] Those particular outcomes most likely to occur have least potential surprise; whereas the outcomes with greater likelihood of occurrence in the decision-maker's mind have a low potential surprise. The potential surprise function is then combined with an individual indifference function in order to arrive at the best strategy selection. The best outcome is the one considered to be producing the largest gain for the decision-maker.

A thorough discussion of all of the criterion is unwarranted in this paper.[13] The various criteria for strategy selection under conditions of ignorance or extreme uncertainty have received a good deal of attention. The intellectual game of "how many ways can you make a decision sound reasonable" has been well played, but insufficient attention has been given to the more important problems of when ignorance should be assumed for decisions under less complete uncertainty.

Summary

The decision-making model under certainty assumes one state of nature in which the payoffs of the various strategies may be predicted perfectly. When the payoffs are presented in optimizing quantities, such as utility, the rule states that the strategy with the largest payoff (under maximization) is selected.

Under conditions of risk, the model constraint of one state of nature can

[10] Leonid Hurwicz, *Optimality Criteria for Decision Making Under Ignorance* (Cowles Commission mimeographed discussion paper, Statistics No. 370, 1951).

[11] L. J. Savage, "The Theory of Statistical Decision," *Journal of the American Statistical Association,* XLVI (1951), 55–67.

[12] G. L. S. Shackle, *Uncertainty in Economics and Other Reflections* (New York: Cambridge University Press, 1955).

[13] A more thorough discussion of most of these criteria can be found in Miller and Starr, *op. cit.*, pp. 85–94.

be relaxed and a finite or an infinite number of states may be assumed. Given the stated conditions, the prediction of payoffs is again assumed to be perfect. Under this model, given (1) the proper strategy alternatives, (2) the payoffs expressed in terms of the value to be optimized, (3) perfect payoff prediction, and (4) a known probability distribution of the states of nature, an optimal strategy may be selected as the best decision. This may be found by selecting the strategy with the largest expected value (to maximize) of payoffs or through an indifference analysis.

The decision-making model most common to the business and managerial field is that involving uncertainty, in various degrees, but usually not total ignorance. Uncertainty may exist when some objective experience is available but not enough to precisely determine the probability distribution of the various states of nature. The case tends to approach risk, but decision-making risk assumes that a probability distribution is known. As the amount of objective experience decreases, the decision-maker must rely more upon the personal feelings or judgment concerning the selection of various strategies. Significant problems in this field are (1) to determine when the objective experience becomes so small that is should be replaced by a subjective probability analysis, or an assumption of ignorance, (2) what techniques can be used to combine effectively subjective probability information, and (3) in general, we need a confidence measure for subjective probability distributions.

Other problems consist of (1) the proper method of measuring risk, (2) the problems of the proper time within which to measure payoffs, (3) the problem of proper enumeration of a reasonable number of payoffs, (4) the problem of measurement of the payoff itself—How precise are the measurement requirements? (5) the use of the appropriate units in which to measure payoffs, and (6) the costs of securing information necessary to determine strategies, states of nature, and payoffs.

ACCOUNTING FOR DECISION-MAKING

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Accounting for decision making involves designing systems that provide relevant information at each stage of the decision-making process: problem formulation, enumeration of alternatives, and choice among alternatives. The amount, accuracy, and frequency of information transmitted are key considerations in information system design. Special as well as routine decisions require new kinds of information not generated in conventional accounting systems.

For many years, the management community has regarded the accounting discipline as one of its principal tools in the decision-making process. The accounting systems of business have traditionally provided much of the financial data and much of the analysis of that data applicable to decision-making purposes. Today, however, there are symptoms of management dissatisfaction with current accounting systems. Many managers believe the accounting function has failed to adjust its objectives and activities to the decision-making requirements of a changing business world.[1]

This charge—that the accounting profession has not kept itself up-to-date—could be the subject of an acrimonious debate. The purpose of this article is not, however, to debate the merits of what accountants have done in the past. We assume neither that accountants are so out-of-touch with the management process as to be obsolete, nor that accountants are so far in the vanguard of newer management movements as to be complacent. Instead of finding fault with the past, we propose to discuss some of the challenges that accounting faces today and in the future. We believe that one of these challenges may be characterized as "accounting for decision-making."

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[1] For a statement of this position, see C. West Churchman and Russell L. Ackoff, "Operational Accounting and Operations Research," *The Journal of Accountancy* (February, 1955), 33–39.

What Is Accounting for Decision-Making?

Accounting for decision-making involves a particular way of viewing the decision-making, or managing, process in business. As characterized in a recent monograph by Herbert A. Simon, the decision-making process does not consist solely of the choice involved between two or more alternatives. The decision-maker is not "the alert gray-haired businessman, sitting at the board of directors' table with his associates, caught at the moment of saying 'aye' or 'nay.' "[2] Decision-making involves

[2] Herbert A. Simon, *The New Science of Management Decision* (New York: Harper & Row, Publishers, 1960), p. 1.

something more than the final choice which is the culmination of the decision process.

As first described by John Dewey,[3] decision-making, problem-solving, or managing may be viewed as involving a three-stage process aimed at answering the following questions:

1. What is the problem?
2. What are the alternatives?
3. Which alternative is best?

What relevance does this decision-making process have to accounting?

The tie between the accounting process and the decision-making process described above is basically one of information. In its broadest and most fruitful sense, accounting is an information or data-providing function—and information of one kind or another is required at each stage of the problem-solving process.

Consider, for example, the first stage of the problem-solving process: What is the problem? A standard cost system is an information system designed to answer this kind of question in a specific, although limited, area. One of the uses of a favorable or unfavorable variance generated by a standard cost system is simply to tell management that it has a problem, a decision to make. A standard cost system doesn't define the alternatives—that requires investigation of the reasons for variance—nor does it tell which alternative is best. The standard cost system is an information device to indicate when there is a problem.

As a further example of the information link between accounting and decision-making, consider the third stage of the decision-making process. Choice of a best alternative requires criteria against which to judge various possibilities. Choice requires information concerning the various alternatives—information cast in a form consistent with the criteria. For example, the choice of investment alternatives may be judged against a rate-of-return criterion, and information about the alternatives must be provided in rate-of-return form. Here we have another case where accounting in the information-providing sense is clearly linked to the decision-making process.

In talking about accounting for decision-making, we are considering perhaps two fundamental characteristics of the information system of a business. These characteristics can be summarized by the following questions:

1. *Which alternative is best?* For any given decision, which is, in fact, necessary, what information is required to make the decision?
2. *What is the problem?* For any given organization and its objectives, what information is necessary to determine what decisions are, in fact, required?

In general, these two questions are related to two management decision areas where much current attention is being concentrated.

The first question is related to "routine" decision problems—regularly recurring problems which are programmed or structured. In controlling inventory, for example, a routine decision is, "How much to buy?" Considerable progress has been made in determining good criteria for such routine decisions and in determining the information necessary to make such decisions.

The second question is largely related to "special" decision problems— irregularly occurring problems which are unprogrammed and unstructured. How and when, for example, should a business undertake a thorough review of its plant location policy or its organiza-

[3] John Dewey, *How We Think,* 2nd ed. (Boston: D. C. Heath & Company, 1933), p. 120.

tional structure? When should a firm consider switching from a policy of price following to a policy of price leadership? How does a business recognize that its routine decisions are uncoordinated?

These two questions, their related problem areas, and current research pose many challenges for the accounting profession. We will first discuss challenges in the routine decision area.

Routine Decisions

In assessing the challenges that accounting information systems present in the routine decision area, it is profitable to review some of the common deficiencies of information systems today.

Over-Information

This is the situation where too much information is made available to the decision-maker. Detailed or refined data are supplied when summary or gross data would suffice. This situation frequently exists where detailed information is required at one decision point, but summary information would be adequate for a decision at another point. As a result, complete detail is given to all users of the data. An example of over-information in military accounting is the detailed costing of nuts and bolts for the indirect reason that detailed unit information is required for inventory control.

On the matter of over-information, a note of alarm should be sounded. Massive quantities of detailed information are available with current electronic data processing systems. Unless these data are properly screened and summarized, the individual manager can easily become flooded with unnecessary information. The manager can spend the bulk of his day ferreting out or summarizing those facts which are required in order to make a decision.

In many installations of data processing systems made to date, there is the serious question whether the needs for information have been adequately considered in the systems design. It is often easier to generate an abundance of data than to go through the difficult process of deciding which data are necessary.

Under-Information

Another characteristic of some present-day information systems is the lack of adequate information to make an appropriate decision. This condition we can refer to as "under-information." Traditionally, accounting systems have recorded only data stated in terms of dollars. For many situations, however, such data are not particularly useful, and other data are required. In item inventory control, for example, unit information is perhaps most important and helpful; dollar data are largely irrelevant. Another example of under-information relates to unfilled orders or lost sales. Information regarding lost sales is apt to be more significant for many decisions than are carefully quantified data on completed sales transactions.

In order to correct problems of under-information, there are two approaches. First, the new methods of processing data are making it relatively easier to supply information which might not normally be accumulated in a typical accounting system. Second, accountants can broaden their interest and responsibility for information stated in nondollar units of measurement—information which is typically needed and required in order to make adequate decisions in many operating areas.

Untimely Information

There are two kinds of untimely information. There is that information

which comes too late, or is supplied less frequently than necessary. There is information which is supplied too often simply because it is prepared routinely. In the first case, accountants have considerable responsibility for getting data to management in a prompt and useful fashion. Monthly financial statements or monthly budget status reports which come out too late to be useful as a basis for corrective action might as well not be generated. In the second situation, there is no need to supply, routinely or regularly, data which are needed only at irregular or sporadic intervals.

There are generally two corrective approaches to the problem of untimely information. There is the concept of exception reporting, which has gained much acceptance today. There is also the proper use of analytical studies. Information systems should be capable of developing an analytical report which is useful in making a particular decision —if and when it is necessary to make that decision. Detailed analytical reports should not be supplied routinely, however, with the idea that they *may be* required for a decision which *may have* to be made.

The Decision-Making View

At the present time, many applications of the accounting for decision-making point of view to routine decision problems are being made in business. These applications are often made in the name of operations research, management sciences, management services, or some other title. Whatever the title, the accountant applying this viewpoint must consider the following series of questions:

1. What is the decision that needs to be made?
2. What is the best rule for making the decision?
3. What information is required in making the decision?
4. How accurate must that information be?
5. How frequently should the information be supplied?
6. What is the most logical source for generating the information?
7. How can the information best be obtained and transmitted to the user?

An information system which is developed after consideration of these questions will not, of course, guarantee that the answers to each problem will be the best possible answers. Rather, this approach to system design guarantees only that the right questions are being asked.

Assume, for example, a particular area of control which has always been a problem—inventory—and consider the relationship of the stated questions to an analysis of a typical inventory control problem.

Decisions which must be made in the routine management of each item of inventory may be stated as follows: How much to buy? When to buy?

Much progress has been made in the spreading use today of the standard lot size formula and reorder point formulas —improved decision rules for determining how much of an item to buy and when to buy it. These improved decision rules create, however, a host of new information problems. It is important to know that these rules require the explicit consideration of certain information which heretofore has often been considered intuitively:

1. The cost, in the opportunity sense, of running out of an item
2. The cost, in the opportunity sense, of holding an item in inventory
3. The cost, in the money sense, of procuring an item
4. The expected future demand for the item

The accounting function is presented with a need for new kinds of information not generated in conventional accounting systems. In addition, the task of evaluating accuracy, timeliness, source, and transmission requirements for these new kinds of data must be performed.

The fact that routine decision rules can be improved by scientific analysis has already been demonstrated in the inventory control, production control, and investment fields. Improved decision procedures, based on such logical analysis as we have described, are being increasingly accepted by business. Current research can be expected to produce further improvements in methods of making routine business decisions.

The implications of these developments for the accounting information function seem fairly clear. Accounting within the firm must concern itself more with integrating information flows with decision requirements. Information flows must be tied directly into decisions which are to be made. Information flows to decision points must be accurate and timely, whether the decision point be a machine, a man, a department, or a board of directors.

In the future, we can expect to learn more about the effects of information frequency (and accuracy) on routine decisions. Tremendous technical strides in methods of information transmission and information reduction can be expected. In particular, electronic data processing and statistical sampling promise revolutionary changes in information processing methods.

Special Decisions

In our discussion of accounting for decision-making as applied to routine decisions, we have assumed the decisions to be made by an organization must first be specified before an intelligent design of the information flow is possible. Determination of the decisions to be made comes properly before specification of the data which should be supplied. Since the decisions which must be made are not always obvious, this brings us back to the first question posed: What is the problem?

To determine what decisions should be made—What is the problem?—is perhaps the essence of the present art of management. It may be considered the highest management art, for, in most instances, it carries with it the highest penalty for failure. An organization which does not recognize that it has a poor system for routine inventory decisions will suffer reduced profits. An organization which fails to recognize in time the necessity for a major investment decision may go bankrupt. An organization which fails to integrate routine decisions with each other and with the objectives of the organization may suffer the same fate, even though the routine decisions are independently well made. But how can management recognize such special problems? At the present time, there are no satisfying answers to these questions.

Although our present fund of knowledge about how problems are recognized is exceedingly meager, we do know a few things, and current research is promising some breakthroughs in this decision area. We know, as we have previously pointed out in connection with a standard cost system, that information of one kind or another is required to recognize problems—to signal that the determination of a lower level decision is required. At the present time, managers acquire the information which spurs problem recognition in many haphazard and random ways. Often the manager must hunt for and search out the information leading to problem recognition.

Nonetheless, it is not too optimistic to hope that, in the future, information systems can be devised which will aid the manager in the problem recognition stage of decision-making. Information systems of the future may be commonly applied to the problem recognition phase as well as to the alternative choice phase of the decision-making process. Under the title of heuristics or heuristic programming, a considerable amount of management service research directed toward such a goal is being conducted today.[4]

Again, we believe the implications of these developments for accounting for decision-making are clear. As business organizations structure their decision activities, it will be with the help of more complex and sophisticated information systems. The responsibility of the accounting information function must, of necessity, increase.

[4] A. Newell and H. A. Simon, "Heuristic Problem Solving," *Operations Research,* VI (January–February, 1958), 1–10.

Perhaps the primary implication of the notion of accounting for decision-making is that accounting practice of today must move ahead, with new thinking and new methods. In the past, the accounting function has been a principal source of information flows within a business. The accounting function in the future will assume an expanded responsibility for information flows. Accounting has an obligation to take a significant part in the development of new quantitative information systems.

As a part of this development, accounting must divert itself from its preoccupation of the past with fiduciary and stewardship responsibilities. Responsibility for fiduciary decisions is a proper and major concern of the accountant. However, if the accountant is to comprehend and contribute to the decision-making, information-flow process within tomorrow's business organizations, he must integrate his stewardship responsibility with a responsibility for broader management decisions.

MANAGEMENT MISINFORMATION SYSTEMS

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Five assumptions commonly made by designers of management information systems are identified. It is argued that these are not justified in many (if not most) cases and hence lead to major deficiencies in the resulting systems. These assumptions are: (1) the critical deficiency under which most managers operate is the lack of relevant information, (2) the manager needs the information he wants, (3) if a manager has the information he needs, his decision making will improve, (4) better communication between managers improves organizational performance, and (5) a manager does not have to understand how his information system works, only how to use it. To overcome these assumptions and the deficiencies which result from them, a management information system should be imbedded in a management control system. A procedure for designing such a system is proposed and an example is given of the type of control system which it produces.

The growing preoccupation of operations researchers and management scientists with Management Information Systems (MIS's) is apparent. In fact, for some the design of such systems has almost become synonymous with operations research or management science. Enthusiasm for such systems is understandable: It involves the researcher in a romantic relationship with the most glamorous instrument of our time, the computer. Such enthusiasm is understandable, but, nevertheless, some of the excesses to which it has led are not excusable.

Contrary to the impression produced by the growing literature, few computerized management information systems have been put into operation. Of those I've seen that have been implemented, most have not matched expectations and some have been outright failures. I believe that these near- and far-misses could have been avoided if certain false (and usually implicit) assumptions on which many such systems have been erected had not been made.

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There seem to be five common and erroneous assumptions underlying the design of most MIS's, each of which I will consider. After doing so, I will outline an MIS design procedure which avoids these assumptions.

Give Them More

Most MIS's are designed on the assumption that the critical deficiency under which most managers operate is the *lack of relevant information*. I do not deny that most managers lack a good deal of information that they should have, but I do deny that this is the most important informational deficiency from which they suffer. It seems to me that they suffer more from an *overabundance of irrelevant information*.

This is not a play on words. The consequences of changing the emphasis of an MIS from supplying relevant information to eliminating irrelevant information is considerable. If one is preoccupied with supplying relevant

information, attention is almost exclusively given to the generation, storage, and retrieval of information: Hence emphasis is placed on constructing data banks, coding, indexing, updating files, access languages, and so on. The ideal which has emerged from this orientation is an infinite pool of data into which a manager can reach to pull out any information he wants. If, on the other hand, one sees the manager's information problem primarily, but not exclusively, as one that arises out of an overabundance of irrelevant information, most of which was not asked for, then the two most important functions of an information system become *filtration* (or evaluation) and *condensation*. The literature on MIS's seldom refers to these functions, let alone considers how to carry them out.

My experience indicates that most managers receive much more data (if not information) than they can possibly absorb even if they spend all of their time trying to do so. Hence they already suffer from an information overload. They must spend a great deal of time separating the relevant from the irrelevant and searching for the kernels in the relevant documents. For example, I have found that I receive an average of forty-three hours of unsolicited reading material each week. The solicited material is usually half again this amount.

I have seen a daily stock status report that consists of approximately six hundred pages of computer print-out. The report is circulated daily across managers' desks. I've also seen requests for major capital expenditures that come in book size, several of which are distributed to managers each week. It is not uncommon for many managers to receive an average of one journal a day or more. One could go on and on.

Unless the information overload to which managers are subjected is reduced, any additional information made available by an MIS cannot be expected to be used effectively.

Even relevant documents have too much redundancy. Most documents can be considerably condensed without loss of content. My point here is best made, perhaps, by describing briefly an experiment that a few of my colleagues and I conducted on the OR literature several years ago. By using a panel of well-known experts, we identified four OR articles that all members of the panel considered to be "above average," and four articles that were considered to be "below average." The authors of the eight articles were asked to prepare "objective" examinations (duration thirty minutes) plus answers for graduate students who were to be assigned the articles for reading. (The authors were not informed about the experiment.) Then several experienced writers were asked to reduce each article to two thirds and one third of its original length only by eliminating words. They also prepared a brief abstract of each article. Those who did the condensing did not see the examinations to be given to the students.

A group of graduate students who had not previously read the articles were then selected. Each one was given four articles randomly selected, each of which was in one of its four versions: 100 per cent, 67 per cent, 33 per cent, or abstract. Each version of each article was read by two students. All were given the same examinations. The average scores on the examinations were then compared.

For the above-average articles there was no significant difference between average test scores for the 100 per cent, 67 per cent, and 33 per cent versions, but there was a significant decrease in average test scores for those who had

read only the abstract. For the below-average articles there was no difference in average test scores among those who had read the 100 per cent, 67 per cent, and 33 per cent versions, but there was a significant *increase* in average test scores of those who had read only the abstract.

The sample used was obviously too small for general conclusions, but the results strongly indicate the extent to which even good writing can be condensed without loss of information. I refrain from drawing the obvious conclusion about bad writing.

It seems clear that condensation as well as filtration, performed mechanically or otherwise, should be an essential part of an MIS, and that such a system should be capable of handling much, if not all, of the unsolicited as well as solicited information that a manager receives.

The Manager Needs the Information That He Wants

Most MIS designers "determine" what information is needed by asking managers what information they would like to have. This is based on the assumption that managers know what information they need and want it.

For a manager to know what information he needs, he must be aware of each type of decision he should make (as well as does), and he must have an adequate model of each. These conditions are seldom satisfied. Most managers have some conception of at least some of the types of decisions they must make. Their conceptions, however, are likely to be deficient in a very critical way, a way that follows from an important principle of scientific economy: The less we understand a phenomenon, the more variables we require to explain it. Hence, the manager who does not understand the phenomenon he controls plays it "safe" and, with respect to information, wants "everything." The MIS designer, who has even less understanding of the relevant phenomenon than the manager, tries to provide even more than everything. He thereby increases what is already an overload of irrelevant information.

For example, market researchers in a major oil company once asked their marketing managers what variables they thought were relevant in estimating the sales volume of future service stations. Almost seventy variables were identified. The market researchers then added about half again this many variables and performed a large multiple linear regression analysis of sales of existing stations against these variables and found about thirty-five to be statistically significant. A forecasting equation was based on this analysis. An OR team subsequently constructed a model based on only one of these variables, traffic flow, which predicted sales better than the thirty-five variable regression equation. The team went on to *explain* sales at service stations in terms of the customers' perception of the amount of time lost by stopping for service. The relevance of all but a few of the variables used by the market researchers could be explained by their effect on such perception.

The moral is simple: One cannot specify what information is required for decision making until an explanatory model of the decision process and the system involved has been constructed and tested. Information systems are subsystems of control systems. They cannot be designed adequately without taking control into account. Furthermore, whatever else regression analyses can yield, they cannot yield

understanding and explanation of phenomena. They describe and, at best, predict.

Give a Manager the Information He Needs and His Decision Making Will Improve

It is frequently assumed that if a manager is provided with the information he needs, he will then have no problem in using it effectively. The history of OR stands to the contrary. For example, give most managers an initial tableau of a typical "real" mathematical programming, sequencing, or network problem and see how close they come to an optimal solution. If their experience and judgment have any value, they may not do badly, but they will seldom do very well. In most management problems there are too many possibilities to expect experience, judgement, or intuition to provide good guesses, even with perfect information.

Furthermore, when several probabilities are involved in a problem, the unguided mind of even a manager has difficulty in aggregating them in a valid way. We all know many simple problems in probability in which untutored intuition usually does very badly (e.g., What are the correct odds that two of twenty-five people selected at random will have their birthdays on the same day of the year?). For example, very few of the results obtained by queuing theory, when arrivals and service are probabilistic, are obvious to managers; nor are the results of risk analysis where the managers' own subjective estimates of probabilities are used.

The moral: It is necessary to determine how well managers can use needed information. When, because of the complexity of the decision process, they can't use it well, they should be provided with either decision rules or performance feedback so that they can identify and learn from their mistakes. More on this point later.

More Communication Means Better Performance

One characteristic of most MIS's which I have seen is that they provide managers with better current information about what other managers and their departments and divisions are doing. Underlying this provision is the belief that better interdepartmental communication enables managers to coordinate their decisions more effectively and, hence, improves the organization's overall performance. Not only is this not necessarily so, but it seldom is so. One would hardly expect two competing companies to become more cooperative because the information each acquires about the other is improved. This analogy is not as farfetched as one might first suppose. For example, consider the following very much simplified version of a situation I once ran into. The simplification of the case does not affect any of its essential characteristics.

A department store has two "line" operations: buying and selling. Each function is performed by a separate department. The Purchasing Department primarily controls one variable: how much of each item is bought. The Merchandising Department controls the price at which it is sold. Typically, the measure of performance applied to the Purchasing Department was the turnover rate of inventory. The measure applied to the Merchandising Department was gross sales; this department sought to maximize the number of items sold times their price.

Now by examining a single item, let

us consider what happens in this system. The merchandising manager, using his knowledge of competition and consumption, set a price which he judged would maximize gross sales. In doing so he utilized price-demand curves for each type of item. For each price the curves show the expected sales and values on an upper and lower confidence band as well. (See Figure 1.)

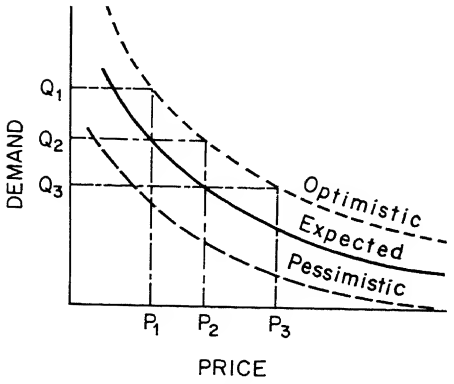


Figure 1

Price-demand curve

When instructing the Purchasing Department how many items to make available, the merchandising manager quite naturally used the value on the upper confidence curve. This minimized the chances of his running short which, if it occurred, would hurt his performance. It also maximized the chances of being overstocked, but this was not his concern—only the purchasing manager's. Say, therefore, that the merchandising manager initially selected price P_1 and requested that amount Q_1 be made available by the Purchasing Department.

In this company the purchasing manager also had access to the price-demand curves. He knew the merchandising manager always ordered optimistically.

Therefore, using the same curve he read over from Q_1 to the upper limit and down to the expected value from which he obtained Q_2, the quantity he actually intended to make available. He did not intend to pay for the merchandising manager's optimism. If merchandising ran out of stock, it was not his worry. Now the merchandising manager was informed about what the purchasing manager had done, so he adjusted his price to P_2. The purchasing manager, in turn, was told that the merchandising manager had made this readjustment so he planned to make only Q_3 available. If this process—made possible only by perfect communication between departments—had been allowed to continue, nothing would have been bought and nothing would have been sold. This outcome was avoided by prohibiting communication between the two departments and forcing each to guess what the other was doing.

I have obviously caricatured the situation in order to make the point clear: When organizational units have inappropriate measures of performance which put them in conflict with each other, as is often the case, communication between them may hurt organizational performance, not help it. Organizational structure and performance measurement must be taken into account before opening the flood gates and permitting the free flow of information between parts of the organization. (A more rigorous discussion of organizational structure and the relationship of communication to it can be found in (1).)

A Manager Does Not Have to Understand How an Information System Works, Only How to Use It

Most MIS designers seek to make their systems as innocuous and unobtru-

sive as possible to managers lest they become frightened. The designers try to provide managers with very easy access to the system and assure them that they need to know nothing more about it. The designers usually succeed in keeping managers ignorant in this regard. This leaves managers unable to evaluate the MIS as a whole. It often makes them afraid to even try to do so lest they display their ignorance publicly. In failing to evaluate their MIS, managers delegate much of the control of the organization to the system's designers and operators who may have many virtues, but managerial competence is seldom among them.

Let me cite a case in point. A chairman of a board of a medium-size company asked for help on the following problem. One of his larger (decentralized) divisions had installed a computerized production-inventory control and manufacturing-manager information system about a year earlier. It had acquired about $2,000,000 worth of equipment to do so. The board chairman had just received a request from the division for permission to replace the original equipment with newly announced equipment which would cost several times the original amount. An extensive "justification" for so doing was provided with the request. The chairman wanted to know whether the request was really justified. He admitted to complete incompetence in this connection.

A meeting was arranged at the division at which I was subjected to an extended and detailed briefing. The system was large but relatively simple. At the heart of it was a reorder point for each item and a maximum allowable stock level. Reorder quantities took lead-time as well as the allowable maximum into account. The computer kept track of stock, ordered items when required, and generated numerous reports on both the state of the system it controlled and its own "actions."

When the briefing was over I was asked if I had any questions. I did. First I asked if, when the system had been installed, there had been many parts whose stock level exceeded the maximum amount possible under the new system. I was told there were many. I asked for a list of about thirty and for some graph paper. Both were provided. With the help of the system designer and volumes of old daily reports I began to plot the stock level of the first listed item over time. When this item reached the maximum "allowable" stock level it had been reordered. The system designer was surprised and said that by sheer "luck" I had found one of the few errors made by the system. Continued plotting showed that because of repeated premature reordering, the item had never gone much below the maximum stock level. Clearly the program was confusing the maximum allowable stock level and the reorder point. This turned out to be the case in more than half of the items on the list.

Next I asked if they had many paired parts, ones that were only used with each other, for example, matched nuts and bolts. They had many. A list was produced, and we began checking the previous day's withdrawals. For more than half of the pairs the differences in the numbers recorded as withdrawn were very large. No explanation was provided.

Before the day was out it was possible to show by some quick and dirty calculations that the new computerized system was costing the company almost $150,000 per month more than the hand system which it had replaced, most of this in excess inventories.

The recommendation was that the system be redesigned as quickly as possible and that the new equipment

not be authorized for the time being.

The questions asked of the system had been obvious and simple ones. Managers should have been able to ask them but—and this is the point—they felt themselves incompetent to do so. They would not have allowed a hand-operated system to get so far out of their control.

No MIS should ever be installed unless the managers for whom it is intended are trained to evaluate and hence control it rather than be controlled by it.

A Suggested Procedure for Designing an MIS

The erroneous assumptions I have tried to reveal in the preceding discussion can, I believe, be avoided by an appropriate design procedure. One is briefly outlined here.

1. Analysis of the Decision System

Each (or at least each important) type of managerial decision required by the organization under study should be identified, and the relationships between them should be determined and flow-charted. Note that this is *not* necessarily the same thing as determining what decisions *are* made. For example, in one company I found that make-or-buy decisions concerning parts were made only at the time when a part was introduced into stock and were never subsequently reviewed. For some items this decision had gone unreviewed for as many as twenty years. Obviously, such decisions should be made more often; in some cases, every time an order is placed in order to take account of current shop loading, underused shifts, delivery times from suppliers, and so on.

Decision-flow analyses are usually self-justifying. They often reveal important decisions that are being made by default (e.g., the make-buy decision referred to above), and they disclose interdependent decisions that are being made independently. Decision-flow charts frequently suggest changes in managerial responsibility, organizational structure, and measure of performance which can correct the types of deficiencies cited.

Decision analyses can be conducted with varying degrees of detail; that is, they may be anywhere from coarse to fine grained. How much detail one should become involved with depends on the amount of time and resources that are available for the analysis. Although practical considerations frequently restrict initial analyses to a particular organizational function, it is preferable to perform a coarse analysis of all of an organization's managerial functions rather than a fine analysis of one or a subset of functions. It is easier to introduce finer information into an integrated information system than it is to combine fine subsystems into one integrated system.

2. An Analysis of Information Requirements

Managerial decisions can be classified into three types:

1. Decisions for which adequate models are available or can be constructed and from which optimal (or near optimal) solutions can be derived. In such cases the decision process itself should be incorporated into the information system, thereby converting it (at least partially) to a control system. A decision model identifies what information is required and, hence, what information is relevant.
2. Decisions for which adequate models can be constructed but from which optimal solutions cannot be extracted. Here some kind of heuristic or search

procedure should be provided, even if it consists of no more than computerized trial and error. A simulation of the model will, as a minimum, permit comparison of proposed alternative solutions. Here too the model specifies what information is required.

3. Decisions for which adequate models cannot be constructed. Research is required here to determine what information is relevant. If decision making cannot be delayed for the completion of such research or the decision's effect is not large enough to justify the cost of research, then judgment must be used to "guess" what information is relevant. It may be possible to make explicit the implicit model used by the decision maker and treat it as a model of type (2).

In each of these three types of situation it is necessary to provide feedback by comparing actual decision outcomes with those predicted by the model or decision maker. Each decision that is made, along with its predicted outcome, should be an essential input to a management control system. I shall return to this point below.

3. Aggregation of Decisions

Decisions with the same or largely overlapping informational requirements should be grouped together as a single manager's task. This will reduce the information a manager requires to do his job and is likely to increase his understanding of it. This may require a reorganization of the system. Even if such a reorganization cannot be implemented completely, what can be done is likely to improve performance significantly and reduce the information loaded on managers.

4. Design of Information Processing

Now the procedure for collecting, storing, retrieving, and treating information can be designed. Since there is a voluminous literature on this subject, I shall leave it at this except for one point. Such a system must not only be able to answer questions addressed to it; it should also be able to answer questions that have not been asked by reporting any deviations from expectations. An extensive exception-reporting system is required.

5. Design of Control of the Control System

It must be assumed that the system that is being designed will be deficient in many and significant ways. Therefore it is necessary to identify the ways in which it may be deficient, to design procedures for detecting its deficiencies and for correcting the system so as to remove or reduce them. Hence the system should be designed to be flexible and adaptive. This is little more than a platitude, but it has a not-so-obvious implication. No completely computerized system can be as flexible and adaptive as can a man-machine system. This is illustrated by a concluding example of a system that is being developed and is partially in operation. (See Figure 2.)

The company involved has its market divided into approximately two hundred marketing areas. A model for each has been constructed as is "in" the computer. On the basis of competitive intelligence supplied to the service marketing manager by marketing researchers and information specialists, he and his staff make policy decisions for each area each month. Their tentative decisions are fed into the computer which yields a forecast of expected performance. Changes are made until the expectations match what is desired. In this way they arrive at "final" decisions. At the end of the month the computer compares the actual performance of each area with what was predicted. If a deviation exceeds what could be expected by chance, the com-

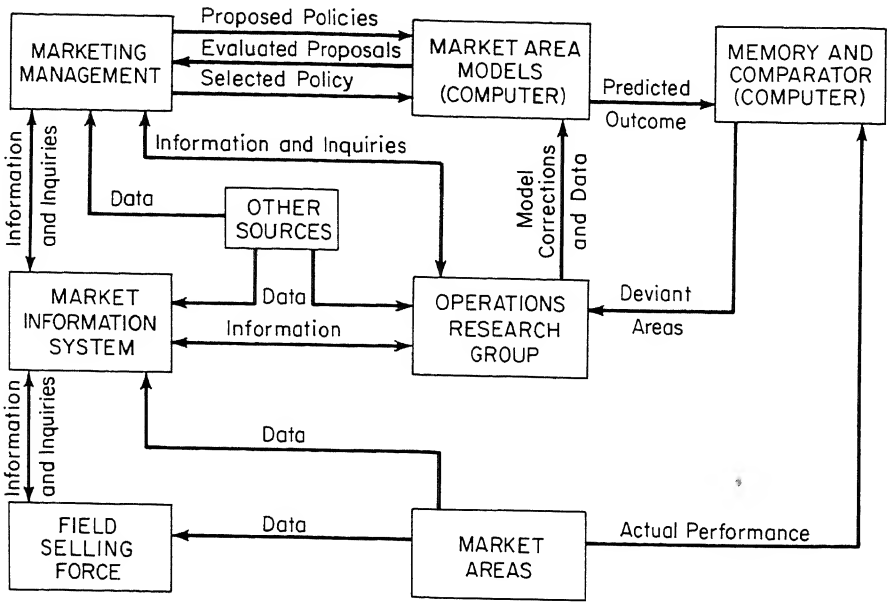


Figure 2
Simplified diagram of a market-area control system

pany's OR group then seeks the reason for the deviation, performing as much research as is required to find it. If the cause is found to be permanent, the computerized model is adjusted appropriately. The result is an adaptive man-machine system whose precision and generality is continuously increasing with use.

Finally, it should be noted that in carrying out the design steps enumerated above, three groups should collaborate: information systems specialists, operations researchers, *and managers.* The participation of managers in the design of a system that is to serve them assures their ability to evaluate its performance by comparing its output with what was predicted. Managers who are not willing to invest some of their time in this process are not likely to use a management control system well, and their system, in turn, is likely to abuse them.

Reference

1. Sengupta, S. S., and R. L. Ackoff, "Systems Theory from an Operations Research Point of View," *IEEE Transactions on Systems Science and Cybernetics,* I (November, 1965), 9–13.

BASIC CONCEPTS FOR DESIGNING A FUNDAMENTAL INFORMATION SYSTEM

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Corporate information systems should be based on the "single information flow" philosophy of data processing. Two new systems analysis techniques are available to meet basic requirements for fundamental information systems. These are data network analysis—for the synthesis phase of the systems study—and source input/output analysis—for the information-gathering phase.

Analyzing a corporate data system is still a primitive process. Although the computer has revolutionized data systems in the past decade, there has been no corresponding revolution in the procedures for installing and operating them. The rationale for determining what data to analyze and how to go about it and the basic techniques for interviewing, documenting, flow charting, and analyzing have changed little since the advent of the computer. Indeed, they have not changed greatly since the nineteenth century.

The large size, complexity, and variety of modern data systems cause continuing difficulties for the systems analyst. Two to eight years, depending on the scope of the application, can elapse from the initiation of a data systems study to its implementation. During this period the systems analyst is beset by continual pressures to get the system operating. Meanwhile, policy changes and personnel rotation are playing havoc with the systems planning.

In general, four major problems handicap present-day systems analysis: (1) a large workload, (2) a long span of elapsed time, (3) a lack of explicit directions both for conducting the study and for using the results, and (4) the lack of a technique to control changes in the data system throughout its life.

These problems are far from being solved. Some new techniques, however, offer promise of alleviating some of them. Data network analysis, which incorporates a method of using the electronic data processor to prepare many of the systems analyses automatically, reduces the total workload and the time span from inception of a study through the preliminary phase. Source input/output analysis facilitates development of the essential information that each functional group within the company needs to operate efficiently. Simulation permits study of the operation of the information system in the form of a model.

This article describes these techniques and explains how they can be applied to the design of an information system, specifically a so-called fundamental information system based on the "single information flow" concept of data processing.

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Information Systems

An information system may be defined as the procedures, methodolo-

gies, organization, software, and hardware elements needed to insert and retrieve selected data as required for operating and managing a company. In this article no distinction is made between so-called management information systems and other kinds of information systems. The term is used to include all specific data required to conduct the business of the company, regardless of whether the data are classified as operating, management, accounting, or any other kind of data.

In many companies the information systems are systems by courtesy only. In the early days of computer technology the components or subsystems approach prevailed. An integrated business system was thought to exist when pieces of information were introduced into the information flow and perpetuated there with a minimum of manual intervention. Mechanization of existing operations—or of data for specific random jobs—resulted in a multiplicity of relatively static systems put together on a piecemeal basis.

Now there is a growing recognition that the interactions and interdependencies among components of a system are more important than the components themselves. Managements are beginning to realize that the information system must be integrated lest data processing become a giant papermill so complex in structure that it is impossible to control.

As Richard E. Sprague has pointed out,[1] fundamental economic and system pressures are fostering a management desire for clean and uncomplicated information systems. Economic pressures include the need for functional and geographic integration of data and the pressure for sharing of computer equipment by users. System pressures, based on the desirability of carrying the processing of data to the user and in other ways making service to him more rapid and more meaningful, include the desire to mechanize data at the source, the need to solve the problems of sharing time on computers that operate on a batch processing basis, and the attractiveness of incorporating on line-real time data processing with current feedback of information to assist management in its decision making function.

These pressures do not operate on every company with equal force, of course. The organization that is considering the design of a new information system should first consider the following questions:

1. How satisfied are people throughout the organization with the existing input and output of information?
2. Have the most recent important changes in data processing operations—manual or computer—been fully "digested" as yet?
3. Have major new technical improvements in systems hardware and software recently become available?
4. Are operating management personnel receptive to new and important changes in the future?
5. Does the organization have designers with the skill and experience needed to develop a new information system?
6. Are the probable time schedules for such a project satisfactory?
7. Are financial budgets adequate?
8. Does the potential payoff justify the effort? Cost and benefit elements of both the present and the proposed system should be analyzed and compared. Figure 1 on page 37 lists the payoff elements normally considered.

If the design of a new information system seems worthwhile, the next question is, "What kind of information system?" As an earlier article in this

[1] Richard E. Sprague, *Electronic Business Systems* (New York: The Ronald Press Company, 1962).

SYSTEM COSTS
Hardware:
- Basic processor
- Storage devices
- Peripheral equipment
- Communication equipment
- Facilities
- Input/output devices
- Equipment maintenance

Total

Operating Expenses:
- Program maintenance
- Equipment operators
- Media preparers (key punchers)
- Data collectors
- Data control and correction
- Utilities
- Cards, paper, etc.

Total

Development Costs:
- Hiring and training of programers and analysts
- Salaries
- Disruption of normal operations
- Retraining displaced personnel

Total

SYSTEM BENEFITS
Decreased Operating Costs:
- Fewer people
- Less inventory
- Fewer penalties for late payment or delivery
- Lower transportation or purchasing costs
- Fewer shortages to interrupt production
- Better scheduling of production
- Better service (internal-external)

Figure 1
System payoff

magazine pointed out,[2] two alternative concepts are being proposed by data processing specialists today. They are the "total" information system, based on the "total systems" approach, and the "fundamental" information system, based on the "single information flow" philosophy.

The total information system, a logical extension of the present subsystems approach, is an attempt to unite all existing information subsystems in the company into a single integrated system. The intent is to include all data for all the needs of all levels of management and operations. Each piece of data is entered in each information subsystem that may need it, with multiple records of similar data as a result.

The fundamental information system, on the other hand, is limited to data considered absolutely essential to the operation of the company. Other data needed for one reason or another by specific user groups are recorded and processed outside the fundamental information system. The fundamental data themselves are recorded only once and stored in a central location.

These two systems are compared in Figure 2 on page 39. Since the author considers the single information flow concept the most promising route to simple and efficient data processing, the remainder of this article will be concerned with the design of a fundamental information system.

Design Principles

The following generalizations represent principles[3] that should be kept in mind when designing the information system:

1. An information system is a system for supplying information to users who

[2] A. F. Moravec, "Basic Concepts for Planning Advanced EDP Systems," *Management Services* (May–June, 1965), 52.

[3] R. J. Chambers, "The Role of Information Systems in Decision Making," *Management Technology*, IV, No. 1 (June, 1964).

must take coordinated action. If effective communication is to take place, the language used must be such that response will be identified by all members of the organization. If action is to be coordinated, the information system cannot be treated as a group of independent subsystems.

2. The information system must remove all doubt about data; that is, the system must be so reliable that the user will depend upon it rather than upon his own observations. For example, information will fail to evoke response (decisions) relevant to the pursuit of its ends if it is found by receivers to be inconsistent with their own direct observations. In this case the system which produces the information will serve to increase rather than to reduce doubt; it will cloud rather than clarify issues confronting decision makers.

3. There is a point at which the marginal cost of differentiation of information and comprehensiveness of information exceeds the marginal utility of information to the receiver; i.e., an individual's capacity for making sound judgments about a complex situation may be seriously impaired by supplying him with a lot of information which he believes would be relevant but whose influence on the situation is not clear to him.

4. Thus, the information system is an abstracting system. Its justification lies in the reduction of the information available to the information that is relevant to action. But abstraction should not be carried to the point where differences in the significance of data are obscured.

5. An information system is a device for continually bringing under notice new facts and new knowledge. It must provide not only the premises of decisions but also a feedback so that decisions may be reaffirmed or abandoned in favor of others. The development of an organization and the development of the judgment of its agents alike depend on this feedback.

6. Since both the capacity and the time available for observation are limited, an information system must provide a formal record to guard against misinterpretation of past experiences. The records of an organization are its memory. Therefore, all records and communications at any time serve not only their immediate function but also the function of memory.

7. The information system must be regarded as a continuously developing instrument, in much the same way as an organization is constantly developing.

8. It is a matter of experience that information processing is done according to habitual modes far more commonly than according to deliberate assessment of the user's requirements.

Requirements

For the fundamental information system to do its job properly, it must meet these requirements:

1. It must provide all the data essential to the operation of the company. These data should include both planning data and performance data. Performance data must measure both planned and present status and must indicate the probable future impact. Cost and financial data should be compared with budget or target dollars; operational schedules should be compared with planned completions; technical quality assurance data should be compared with established standards.
2. The system must be responsive to management needs. This responsiveness can be obtained by "designing in" the flexibility and adaptability needed to reallocate resources as required. By means of computer simulations of management decision making requirements, for ex-

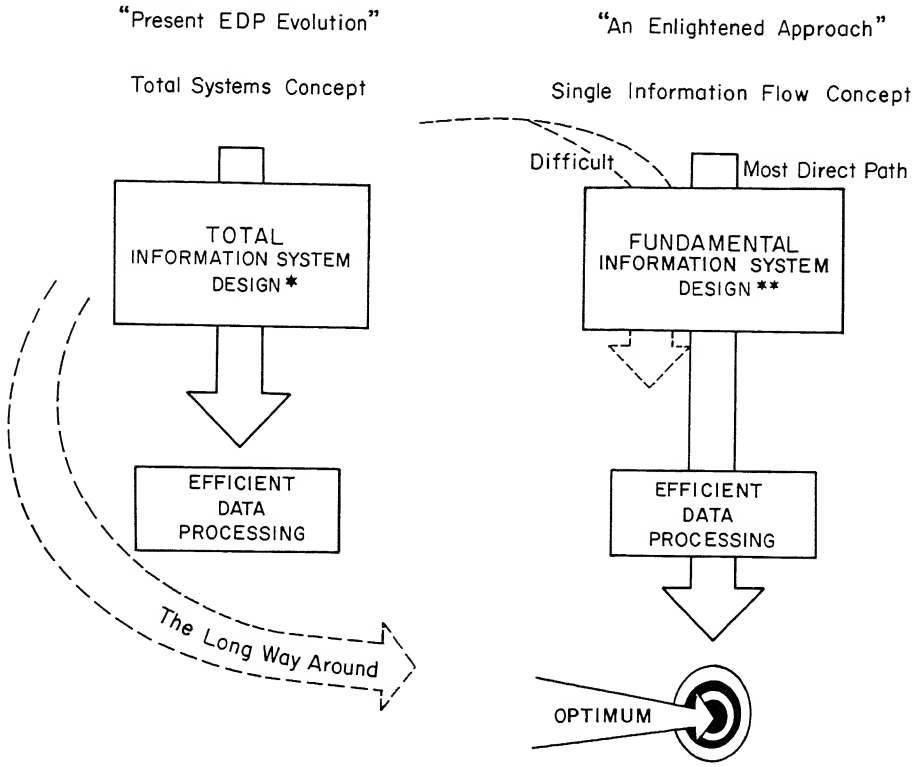


Figure 2

Concept comparison between "total" and "fundamental" information systems

Foundation for "total" information system:

1. Includes all basic interacting and interrelating data in attainable subsystems.
2. It attempts to satisfy all data requirements for all levels of management and for all operating needs.
3. All required or desired data will be included in the information data reservoir.
4. It is envisioned that this data reservoir or data bank will certainly be the larger of the two.
5. Record lengths will be smaller, but the system will include multiple records of similar data.
6. Because of tradition and the desire to use what one already has developed, this kind of an information system will be difficult to construct. Many obstacles including complex data integration and handling will have to be hurdled.

Foundation for "fundamental" information system:

1. Includes only "essential" or "fundamental" data required to effectively operate the firm as a complete entity.
2. It satisfies only the basic data needs of the firm to accomplish its mission and provides the "selective" feedback information necessary for management decisions at the proper level and station.
3. "Nonessential" or "secondary" classed data desired by some operation or by some level of management will be processed off line by peripheral equipment and will not be included in the primary information data reservoir. (Until full conversion, most "secondary" type data will be processed in their present fashion as subsystems.)
4. It is envisioned that this data reservoir or data bank will be the smaller of the two.
5. Record lengths will be long and many, but only single records will prevail.
6. Since this system involves a completely new development approach, ties with the previous EDP environment are severed, making this the most direct and hence the shortest path to the target of optimum data processing.

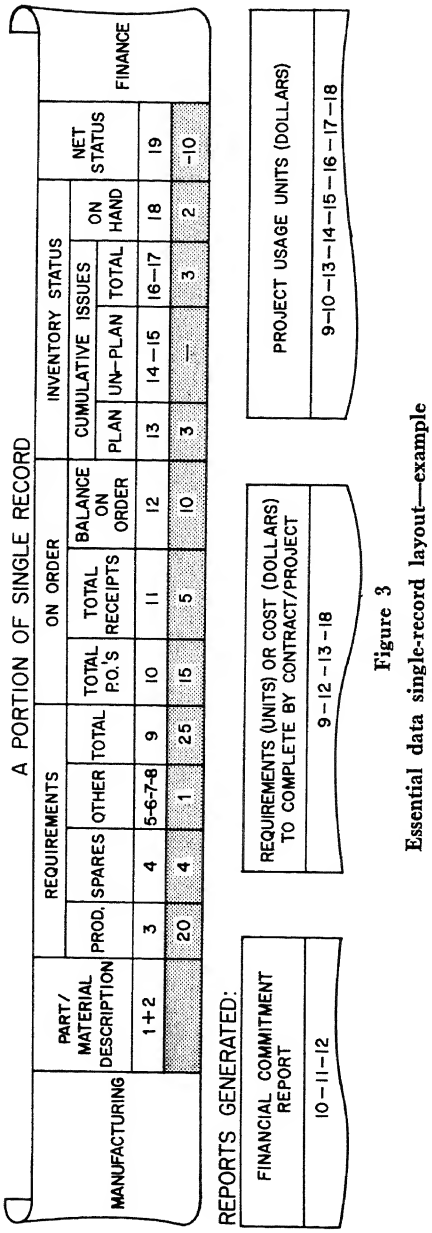


Figure 3
Essential data single-record layout—example

ample, the type and frequency of changes in programs and resource allocations can be tested, and likely condition boundaries can be established.

3. It should be capable of "dynamic self-reprogramming," i.e., able to reprogram itself to meet the ever changing demands of the company. (This is a part of the single information flow concept and its design.)

Systems Analysis

To analyze the interaction of functions and departments using today's methods of operation and then to design the optimum system for mechanization using tomorrow's methods is a complex task involving complex human factors.

A completely new method of analyzing systems and describing information requirements is needed. Such a method should fulfill two requirements:

1. For understandability and workability, the method should present the system in the form of a network in order to permit visual display of data dependencies and interactions; in order to pinpoint communication requirements (volumes, load, frequencies, stations, and the like); and in order to facilitate mathematical treatment (network theory, traffic or queuing theory, linear programming, PERT/Time/Cost, and the like).
2. The principle of data feedback must be incorporated in order to ensure the availability of those data required for management decision making and also to provide a basic structure for decision making simulation programs.

Data Network Analysis

Two new systems analysis techniques are available that meet these requirements. They are data network analysis —for the synthesis phase of the systems study—and source input/output analysis —for the information-gathering phase.

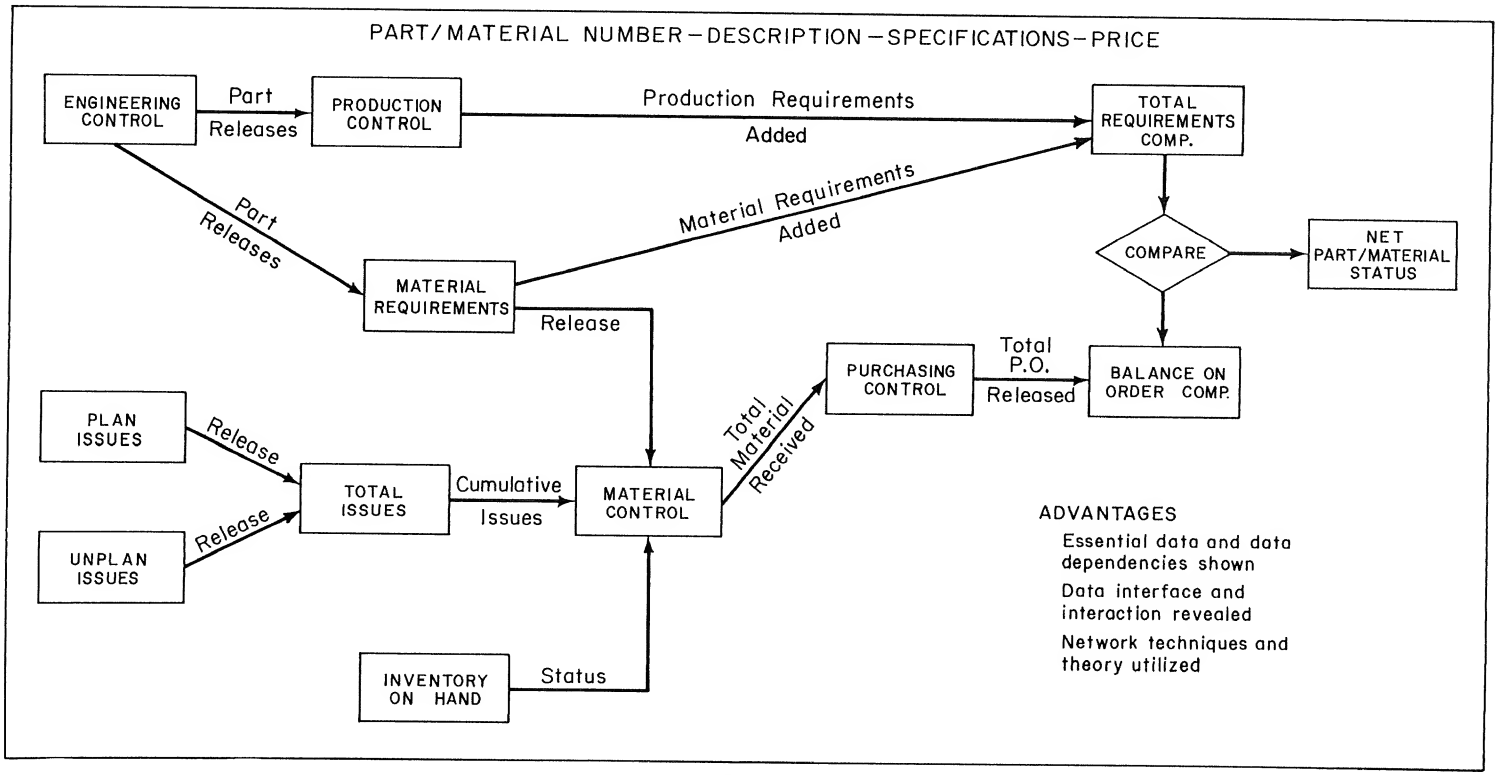


Figure 4

Data network—example

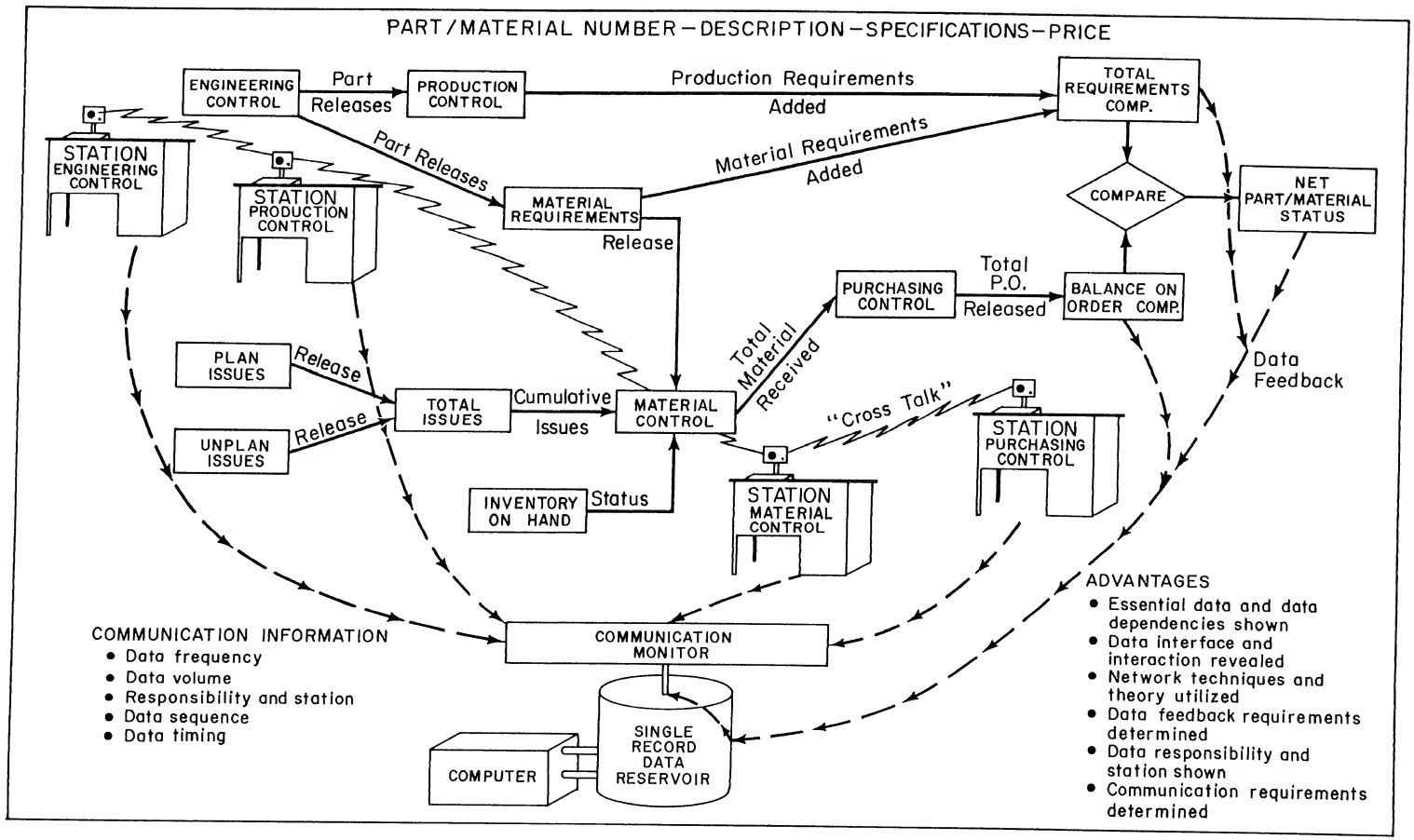


Figure 5

Communication and data network—example

Data network analysis[4] is illustrated in Figures 3, 4, and 5. With this technique, data storage points in the system are analyzed and converted to single records as indicated in Figure 3; each record's characteristics, the activity in and out, and the data elements it contains are detailed.

With this method of analysis, the analyst prepares a flow chart of "event chains" and activities rather than of documents. In this way he can trace the flow of data and actions throughout a data network as they are created and as they respond to events instead of trying to categorize them into arbitrary segments of an information system under such nebulous labels as "applications." Figure 4 shows a simple data network; Figure 5 shows the same data network in conjunction with a computer communication network. One advantage of this technique is that the computer can be programmed to prepare much of the initial systems analysis and documentation automatically.[5]

This data network methodology provides a visual representation of data and action dependency and interdependency, time sequencing of both data and action, load and volume analysis for communication and equipment purposes, and, as a by-product, automation of analysis and documentation. Using the computer to prepare systems analyses automatically—although it does not relieve the systems analyst of any of his usual analysis and design responsibilities—speeds up the preliminary analysis phase of the study and at the same time makes possible a more thorough analysis than can be prepared with present methods.

[4] Arthur D. Hall, *A Methodology for Systems Engineering* (Princeton, N. J.: D. Van Nostrand Co., Inc., 1962).

[5] With some modifications, this technique is similar to Autosate, an automated data systems analysis technique developed by the Rand Corporation.

Determining records and data characteristics, volumes, relationships, and data storage needs gives the analyst a sound basis for design of a new data system. In addition, the data network analysis technique permits the tracing of data and their highly intricate chain reactions throughout the structure of the organization; in the process, user demand and users' effects on each other can be measured.

Because of the complexity of the task of defining a fundamental information system that crosses department lines and includes many functions, data network analysis should be preceded by source input/output analysis.[6] Assuming the systems designer has postulated that all information to be inserted into or withdrawn from the system by each point of origin (source) will be stored centrally and will be available on a real time basis as needed, the procedure for conducting input/output analysis is as follows:

Source Input/Output

1. The characteristics (functions, departmental mission) of each point of origin are identified. The true source of information generated at each point of origin (station) and the information required by each are described in detail.
2. The information that must be held in central storage to satisfy all operating and management requirements is specified in detail. For management-type information, a set of decision rules based on the objectives, policies, and procedures of the organization is inserted into central storage.
3. For communication purposes, the

[6] Robert H. Gregory and Richard L. Van Horn, *Automated Data Processing Systems —Principles and Procedures,* 2nd ed. (Belmont, Calif.: Wadsworth Publishing Company, Inc., 1963).

message formats and lengths for transmission to and from each point-of-origin central point are defined. In addition, the information volumes, i.e., the number of messages per hour for each hour and for each point of origin, are estimated.

4. The sum total of all information generated, stored, and processed for each point of origin and each communication channel and for the central computer location is computed.

These data are then placed on a network for the synthesis phase of the systems study.

The basic steps in designing the information system may be summarized as follows:

1. Determine management's needs to monitor the enterprise as a whole.
2. Design the fundamental information flow, indicating the relationships among the major functions and data, for example, engineering, manufacturing, procurement, marketing, and finance.
3. Develop in detail the "essential" information that each function requires to operate efficiently.
4. Determine each function's data and action requirements and each function's dependence upon other functions' actions and/or information.

Administratively, the plan for conducting the systems study breaks down into three time phases. The first phase, investigation, consists of construction and testing of a simulation model of the system and of source input/output analysis. The second phase, that of preliminary design, includes merging and synthesis of the information gathered in the first phase, preparation of a composite data network analysis, complete initial design of the overall system, and design and testing of a workable automated system. The final phase, final design, consists of complete initial design of system details, selection of equipment configuration, and preparation of a plan for implementation of the information system.

Investigation Phase

The initial investigation—the first phase—calls for a simultaneous two-pronged attack. One group, composed of operations analysts, is responsible for preparing an information system model with a resultant computer simulation model. This process is illustrated in Figure 6.

Simulation is a technique whereby a system and its associated sequence of events are reproduced in the computer; that is, the computer is made to act like the system being studied. These simulation programs are usually referred to as "models," since they are representations of the real system.

At the same time another group, composed of systems analysts, is responsible for preparing an information system based upon review and analysis of present operations, subsystems, and data flows. Using the source input/output systems analysis approach, they determine and define "essential" data and secondary data, review present subsystem applications, prepare a network indicating data dependencies and interactions, design a single-record layout and data flow processing scheme, prepare preliminary conversion specifications, prepare a data and communication network flow, and prepare and assemble documentation.

Both groups must operate under the same systems objectives, goals, and criteria. These are established early in the study and revised as required. Examples follow:

Objectives

1. Determine management's needs to monitor the whole enterprise.

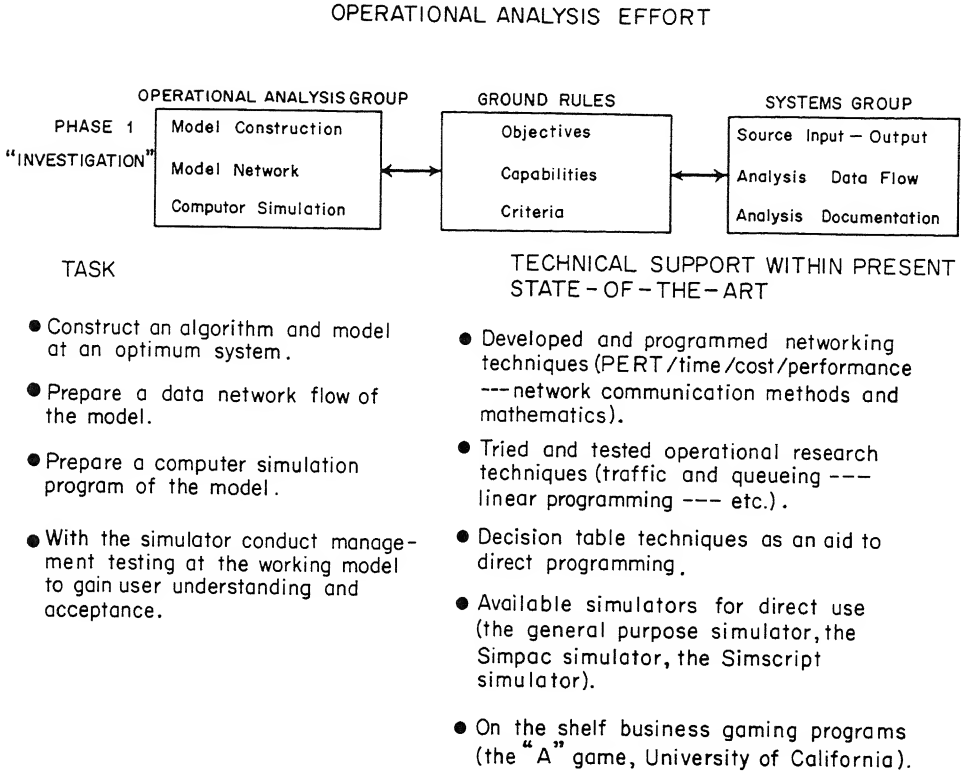


Figure 6

Plan for designing an information system

2. Provide for single-transaction and complete processing of "essential" data and complete single records and data storage.

Capabilities

1. Include planning and performance data within single records of essential data.
2. Provide for timely responsiveness to dynamic management needs, including self-reprogramming abilities.

Criteria

1. Does the system automatically provide for dependency tests of needed data by the user? That is, how long will these data be required?
2. Do outputs result in the required coordinated action?
3. Does the cost difference for data exceed the marginal utility of the information to the user?
4. Does the system provide for selective data feedback for operational needs and management decisions?

Modeling Techniques

The operations analysts are responsible for preparing an optimum information system based upon the analyses of the total requirements of the organization. Their output is a network simulation model with computer programs. The model and programs are then tested by management to assure their practicability and management's understanding and acceptance of them.

This effort need not start completely from scratch. Modeling techniques have already been developed, programmed, and tested by various commercial and governmental organizations. As a result, various state-of-the-art modeling "disciplines" are available for use by the operations analysts. These include such networking techniques for both data and communications as PERT/Time/Cost-Performance methods; such operations research techniques as traffic analysis, queuing theory, linear programming, and the like; decision table techniques; and business simulators and gaming techniques such as the University of California's business game, the General Purpose Simulator, SIMPAC, SIMSCRIPT, and the like. Many of these management science techniques have been described at some length in previous issues of *Management Services.*

Use of these more or less standard tools will substantially reduce the time required for systems design and thus decrease its cost. With their aid the task becomes an applied science rather than a research and development project. The significant part of the effort will be to determine the fundamental requirements of the particular organization and its management's essential decision-making requirements and then to fit these requirements or parameters

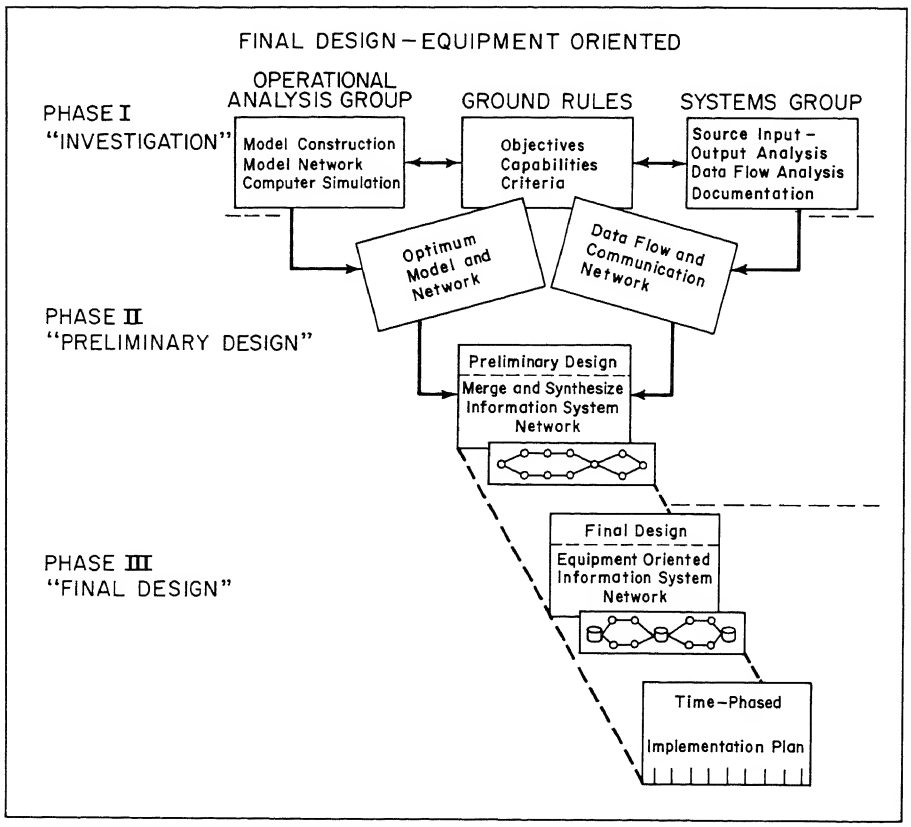


Figure 7
Plan for designing an information system

within the appropriate "disciplines."

Meanwhile the systems analysts have the mission of preparing, as an output, a network reflecting present mechanized data dependencies, data interactions, and data flow and of defining "essential" and "secondary" data. The use of source input/output analysis and data network analysis will greatly aid them in this effort, and will speed their work.

When both groups have completed their assigned tasks, their next step is to unite their efforts to produce the initial data network or preliminary information system. The operations analysts will attempt to adhere to their streamlined model, while the systems analysts will attempt to utilize, insofar as is possible, the "best aspects" of the installed applications and subsystems that are currently in operation.

This preliminary design will be reviewed, analyzed, and modified as necessary. Then a second-cut data network, reflecting the anticipated equipment configuration and required equipment capabilities, will be produced in the final design phase. All three phases of the plan for systems design are illustrated in Figure 7.

A fundamental information system, designed with the aid of these new systems techniques, should go a long way toward solving the problem of the information explosion. Present-day data processing systems are pouring forth more information than anyone can ever hope to assimilate under present circumstances. The ability to generate information has outrun the ability to comprehend it.

Existing information subsystems and application-oriented techniques are not organized so as to permit effective study of the business complex in proper depth. Hence, it is nearly impossible to arrive at solutions revealing the optimum business decisions and the lowest cost alternatives.

The time and money spent in designing a fundamental information system as outlined here should produce many benefits:

1. By means of these techniques the entire fundamental concept of operating the company is studied, perhaps for the first time. The result should be a single-thread flow of information.

2. Previously unrecognized problem areas and bottlenecks will be uncovered. Data processing activities, manual or mechanized, which are now efficient and should continue despite the adoption of new methods will be isolated. The number of reports and the demand for meaningless data can be reduced, to everyone's relief.

3. The study should produce a data processing system that justifies its cost, since it will be based on solid present and future requirements. One objective of the study must be to find that point of balance at which the payoff expected from the data, documents, reports, and analyses produced is at least equal to —if not greater than—the quantity and cost of data processing to be produced. Since every step taken to improve the accuracy of data transmission increases the cost, the study must include determination of the degree of data accuracy actually required for effective management.

4. The study—as a catalyst—will help to initiate new systems thinking throughout the organization to match third-generation computer equipment capabilities. It will incorporate or at least foster such scientific techniques as simulation and decision tables, standards engineering, operations analysis, and cost/performance effectiveness analysis.

Management decision making in the new era can be made at a level of information availability never before dreamed of. This means not just more information faster but mathematically

preanalyzed and preselected information from which meaningless data have been culled.

To maintain control and measure the results of business activity is management's responsibility. To do this within a complete information system, the manager must understand the model construction so well that he can assure himself that the solutions coming from these models will reflect policies that will lead to minimum operational costs. Otherwise a manager may be forced into rubber stamping a computer solution. If management is to manage, the decision makers must take the lead in understanding, designing, and approving the model of the fundamental information system.

Editorial Comment for Chapter 1

If one accepts the fundamental premise that information systems design should serve the aims of decision making, then contemporary theories of management decision making should hold promise of relevance for the information planner. Archer lucidly discusses the varying degrees of information available to decision makers and the relevant decision theory structure for each condition. Davidson and Trueblood emphasize the decision-making viewpoint in their enumeration of seven basic considerations for the development of information. Moravec offers both concepts and application techniques for designing information systems. Each of their articles will be discussed briefly before a somewhat more detailed examination of Ackoff's provocative article is undertaken.

Archer's paper serves to underline that advances in management science will continue to place new and more demanding data requirements on information systems. Management decision models employing new planning and control techniques are increasingly becoming an integral part of management information systems. These models, particularly strategic planning models, must generally be developed under conditions of uncertainty. Certainty is a luxury not often found in management systems and is appropriately given only cursory treatment by Archer.

The introduction of uncertainty into the theory of choice has direct relevance to information system design. Despite some significant data problems to be discussed in Part II, it seems reasonable to predict that deterministic information systems in probabilistic settings will become continually less useful and tolerable. Given the existing and contemplated state of information technology, one of the principal obstacles to probabilistic information systems is the possible reluctance and / or inability of decision makers to think in probabilistic terms.

Should one conclude then that the proper role of information systems is the reduction of uncertainty in the mind of the decision maker? I believe that this proposition is not universally valid. Instead, let us propose that the role of management information systems is to enhance the probability that the decision maker will make soundly conceived decisions, as measured by the goals and complementary standards of decision making of the organization.

Uncertainty reduction as the exhaustive function of information systems can be criticized on two major grounds. First, it does not properly consider the tradeoffs between certainty and gain so basic to our economic way of life. In many instances

the marginal costs of attaining a reduction in uncertainty may well exceed the related marginal benefits. Second, information may increase rather than decrease the decision maker's perceived uncertainty. This occurs when the unwarranted certainty inherent in the decision maker's naive model of the environment is transformed into a more realistic, complex model that explicitly introduces warranted uncertainty.[1] Surely, exhibiting the nature of uncertainty is a fundamental task of management science and information systems.

It is interesting to note the similarities between Davidson and Trueblood's general seven-point approach to information system design and Moravec's more detailed presentation. For example, Davidson and Trueblood ask what the decision is that needs to be made, while Moravec calls for the identification of decision centers as part of source input / output analysis. Davidson and Trueblood discuss decision-making rules, while Moravec emphasizes managerial objectives. The interested reader may wish to contrast the approaches taken in these two articles in further detail.

While data requirements for routine decisions are not always apparent, the greater difficulty associated with special or nonprogrammed decisions is cited by Davidson and Trueblood. Herbert Simon, in his *The New Science of Management Decision*,[2] characterizes nonprogrammed decisions as "novel, unstructured, and consequential." The potential payoff for a well-conceived information system to support this strategic area of decision making is undoubtedly impressive. If information systems are to serve the purpose of strategic decision making, then traditional systems must move from their heavy emphasis on internal financial data to incorporate critical environmental and competitive data. The main thrust of this external information is illustrated by the following list of major topics of concern to decision makers questioned in surveys[3]:

Category	*General Content*
1. Market potential	Supply and demand considerations for market areas of current or potential interest, e.g., capacity, consumption, imports
2. Structural change	Mergers, acquisitions, and joint ventures involving competitors; new entries into the industry
3. Competitors and industry	General information about a competitor, industry policy, concerted actions in the industry, and so forth

[1] Richard M. Cyert and James G. March discuss the related notion of "uncertainty avoidance." "Organizations avoid uncertainty: (1) They avoid the requirement that they correctly anticipate events in the distant future by using decision rules emphasizing short-run reaction to short-run feedback rather than anticipation of long-run uncertain events. They solve pressing problems rather than develop long-run strategies. (2) They avoid the requirement that they anticipate future reactions of other parts of their environment by arranging a negotiated environment. They impose plans, standard operating procedures, industry tradition, and uncertainty-absorbing contracts on the environment." [*A Behavioral Theory of the Firm* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963), p. 119.]

[2] Herbert A. Simon, *The New Science of Management Decision* (New York: Harper & Row, Publishers, 1960).

[3] Francis Joseph Aguilar, *Scanning the Business Environment* (New York: The Macmillan Company, 1967), p. 40.

4. Pricing	Effective and proposed prices for products of current and potential interest
5. Sales negotiations	Information relating to a specific current or potential sale or contract for the firm
6. Customers	General information about current or near-potential customers, their markets, their problems
7. Leads for mergers, joint ventures, or acquisitions	Information concerning possibilities for the manager's own company
8. Suppliers and raw materials	Purchasing considerations for products of current or potential interest
9. New products, processes, and technology	Technical information relatively new and unknown to the company
10. Product problems	Problems involving existing products
11. Costs	Costs for processing, operations, and so forth for current and potential competitors, suppliers, and customers, and for proposed company activities
12. Licensing and patents	Products and processes
13. General conditions	Events of a general nature: political, demographic, national, and so forth
14. Government actions and policies	Governmental decisions affecting the industry
15. Resources available	Persons, land, and other resources possibly available to the company
16. Miscellaneous	Items not classified elsewhere

The precomputer era may be characterized as one of organizations in search of information technology. The past decade, with all its startling advances in information technology, has ushered in an era of information technology in search of "intelligent" organizational users. In light of this latter development, Ackoff's identification and critical examination of the assumptions made by designers of management information systems is particularly timely.[4] Ackoff enumerates the following as basic assumptions underlying management information systems design:

1. The critical deficiency under which most managers operate is the lack of relevant information.
2. The manager needs the information he wants.
3. If a manager has the information he needs, his decision making will improve.
4. Better communication between managers improves organizational performance.
5. A manager does not have to understand how his information system works, only how to use it.

Ackoff proposes that these assumptions are unwarranted in many (if not most)

[4] The following discussion is based upon the author's comments in "Management Misinformation Systems—Another Perspective," *Management Science,* XV (December, 1968).

cases and lead to major deficiencies in the resulting systems. Let us examine briefly these assumptions and the supporting illustrations presented in the Ackoff paper.

Ackoff contends that managers suffer more from an overabundance of irrelevant information than they do from lack of relevant information. This is followed by the suggestion that information be filtered (evaluated) and condensed to reduce the information overload. In the face of seemingly endless pages of computer print-outs, book-size requests for capital expenditures, and other forms that consume unnecessary hours of managers' time, suggestions leading to filtered and / or condensed information are likely to be greeted with enthusiasm. This does, however, raise another important issue. What are the useful limits to filtration and condensation?

Just as processing leading to information overload[5] is not in the best interests of the organization, indiscriminate filtration and "overcondensation" can likewise lead to non salutary results. For example, consider the case of major capital investment proposals originating from various divisions of a company. Assume that for headquarters book-size capital expenditure proposals are now condensed to a single listing of proposed projects (with brief descriptions) and ranked according to some criterion function such as internal rate of return. The headquarters group has two basic options: (1) to accept the divisional estimates or (2) to make a subjective adjustment to compensate for estimated divisional bias.[6] Neither of these alternatives is very comforting, since there is no compelling basis for choice except perhaps assessing past behavior—a choice which may be neither instructive nor relevant. Here, then, is clearly a case of "overcondensation," since the report received by headquarters cannot be used to make an intelligent appraisal of the proposals competing for scarce resources because information about the uncertainty underlying key market and cost variables is not available. "Overcondensation" can occur even if risk analysis techniques are actually employed in a company.

[5] For an informative discussion of information overload, see Daniel Katz and Robert L. Kahn, *The Social Psychology of Organization* (New York: John Wiley & Sons, Inc., 1966), pp. 229–35. As cited by Katz and Kahn on p. 231, responses to information overload are classified by James G. Miller into the following seven categories: "(1) omission, failing to process some of the information; (2) error, processing information incorrectly; (3) queuing, delaying periods of peak load in the hope of catching up during lulls; (4) filtering, neglecting to process certain types of information, according to scheme of priorities; (5) approximation, or cutting categories of discrimination (a blanket and nonprecise way of responding); (6) employing multiple channels, using parallel channels as in decentralization; and (7) escaping from the task." ["Information Input Overload and Psychopathology," *American Journal of Psychiatry,* CXVI (February, 1960), 695–704.]

For a discussion of relief measures from information overload, see Herbert A. Simon, "Information Can Be Managed," *Think,* XXXIII (May–June, 1967), 9–12; and Elias H. Porter, "The Parable of the Spindle," *Harvard Business Review,* XI (May–June, 1962), 58–66.

[6] Donald H. Woods notes the practice in companies of "rewarding the manager whose investment performance exceeds his original forecast and penalizing the one whose performance falls below the forecast. . . . The district managers are quick to interpret the implications this type of reward system has for the choice of forecast which they initially report; they react by choosing a conservative estimate for transmission upward to top management so they will have a greater chance of eventually exceeding it." ["Improving Estimates That Involve Uncertainty," *Harvard Business Review,* XLIV (July–August, 1966), 91–98.]

The following situation illustrates this:

> When analyzing the risk associated with capital investments, subjective judgments are collected and built into some type of model; the results are handed to management, along with a statement to the effect: Here are our analytical results based on the information that you gave us. You must now make the judgment. Although the results are extremely sensitive to the method of collecting the input data and building the model, the literature goes into almost no detail about gathering inputs. I can imagine that management could go ahead on the basis of these results, with the secure feeling that their decisions were scientifically respectable, when actually these decisions were based on wild guesses.[7]

In brief, then, the undesirable state of "overcondensation" is reached when the decision maker no longer has a sound basis for judging the validity of transmitted information.

Filtration has potential as an effective adjustment in the face of information overload. The key question is where in the system should filtration decisions be made? If these decisions are initiated largely at the lower levels of the organization, one might question the limited perspective underlying them. Filtration decisions made at the highest level of the organization, however, offer little or no relief from information overload. The relevant strategy, then, is a function of the confidence that executives have in the filtration decisions made by managers at lower levels.

To illustrate this in the context of the capital expenditure analysis example, consider a set of projects enumerated by the divisions for review by the headquarters group. This set consists only of those projects proposed for adoption and excludes projects rejected at the divisional level. Hence, the information presented to headquarters is indeed filtered. If there are no serious conflicts between the way divisions and headquarters perceive organizational objectives and their attitudes toward risk are identical, then the filtered list of projects is in all probability justified. In the overwhelming majority of cases in which the ideal headquarters-divisional relationship does not exist, it would seem to be more appropriate to ask divisions to enumerate their total set of project opportunities with an "accept" or "reject" recommendation for each.

In summary, while neither information overload nor overfiltration and overcondensation represents an attractive alternative, managers can often make reasonable adjustments to compensate for information overload. Overfiltration and overcondensation tend to accentuate the biases of lower-level managers and provide the executive decision maker with an inadequate basis for making necessary adjustments. The relevant information for managers is somewhere on the continuum between overfiltration and overcondensation, and information overload.

Ackoff argues that the conditions for a manager to know what information he needs are rarely satisfied. The principal problem here is that the decision maker's own conception of an appropriate decision model to fit a specific situation is generally not well developed. I would fully subscribe to Ackoff's subsequent plea

[7] Harry Stern, "Information Systems in Management Science," *Management Science,* XIII (April, 1967), 541.

for active collaboration among information systems specialists, operations researchers, and managers in the various stages of systems design as the best available strategy for overcoming this deficiency.

The respective roles of the operations researcher-information specialist and manager can be illustrated in the context of the service station problem presented by Ackoff. I would envision the main thrust of the manager's responsibility to be: first, to recognize occasions for making decisions and then to frame appropriate questions in light of the decisions to be made. The manager in the major oil company, for example, finds it necessary to make decisions concerning locations of future service stations. An appropriate criterion for making the decision may be sales or profit maximization, subject to certain technological and management-imposed constraints. The manager clearly wants information about future sales potential for alternative service station locations. *And the manager needs the information that he wants.*

While the task of enumerating relevant variables for forecasting equations should be conducted jointly by the operations researcher and manager, in most situations it would be reasonable to expect that model choice and refinements are largely the domain of the operations researcher. The choice of a statistical forecasting model in this case or any model, in a more general case, calls for the exercise of careful judgment on the part of the operations researcher. Problem type, relative importance of the problem, time available before the decision must be made, and expected degree of utilization of model results by decision makers all qualify as strategic considerations in choosing among alternative models. Finally, the results should be presented to the manager in easily understood form, without resorting to either information overload or overcondensation.

Ackoff points out that, because of the complexity of the decision process, managers oftentimes cannot use information well. To support this contention, he suggests that most managers furnished with an *initial* tableau of a typical mathematical programming, sequencing, or network problem are unlikely to come close to an optimal solution. While once certainly would not want to argue with the validity of this proposition, its relevance to the main argument must be questioned. Specifically, I would submit that to furnish a manager with an initial tableau *is to furnish him with data, not information.*[8] The fact that managers cannot easily convert data into information underlies the very need and justification for developing management decision models. If managers could independently iterate from an initial to a final tableau, the simplex and other related algorithms would become redundant and unnecessary. In the Ackoff case the manager is

[8] "The term "data" is used here to represent messages that can be available to the individual but which have not as yet been evaluated for their worth in a specific situation. All communications in a firm may be considered as some form of data processing. "Information" is used here as the label for *evaluated data* in a specific situation. When the individual singles out one of his problems and finds among his data materials that help him solve his problem, he is converting or isolating information from data. Note that a given message may remain constant in content and, yet, under this approach change from data to information when it is put to use in making a decision." [Adrian M. McDonough, *Information Economics and Management Systems* (New York: McGraw-Hill Book Company, 1963), pp. 71–72.]

not provided with information until the results appearing in the final tableau are communicated to him. At that juncture we can only hope that his decision making will improve.

In brief, then, Ackoff's illustration fails to invalidate the assumption that if a manager has the information he needs, his decision making will improve because the decision maker was not provided with the *information* he needed. Perhaps, a more interesting and significant question to ask is to what extent does the information the manager really needs (e.g., final tableaus) improve decision making?

It is true that better communication between managers does not necessarily improve organizational performance. Ackoff's example involving a purchasing and a merchandising department in a department store illustrates this point. I believe it is important to emphasize, however, that the origin of the problem described does not lie in the communication, but instead in the conflicting measures of performance use to judge the two departments. Ackoff, thus, has properly established that interdepartmental communication among departments with conflicting measures of performance may not only be of doubtful value but may actually work counter to the best interests of the organization as a whole. However, the proposition that well-conceived interdepartmental communication enables managers to coordinate their decisions more effectively when appropriate, nonconflicting measures of performance are present was not invalidated.

Ackoff's challenge to the notion that a manager need not understand how an information system works, only how to use it, is particularly significant. It is difficult to debate the merits of this assumption without a more detailed agreement concerning the degree of understanding Ackoff would require of managers. The best available evidence of intent can be gleaned from the case study presented.

A computerized production and inventory control system was discovered to be costing the company almost $150,000 per month more than the former manual system. Most of this cost was attributed to excess inventories. Apparently, a major cause of unreasonable inventory accumulation was a program error that confused the maximum allowable stock level and the reorder point. To suggest that the manager understand the information system to a point where he would detect the programming error seems neither reasonable in an organizational plan nor an economical use of the manager's time. Indeed, to argue for understanding and analysis by managers at this level of detail is legitimate cause for cries of "information overload." A more constructive approach would suggest that a manager should have developed techniques and guidelines using exception reporting for discovering a situation in which an "improved" system costs $150,000 more than its unglamorous predecessor. Perhaps, even more important, the manager would be well advised to develop a more reliable system for hiring better systems designers.

In conclusion, I agree with Ackoff's contention that no management information system "should ever be installed unless the managers for whom it is intended are trained to evaluate and hence control it rather than be controlled by it," but my agreement is within the context explained above. To insist upon *detailed* systems

design knowledge by managers as a prerequisite for new management information systems is tantamount to calling for an information systems moratorium or, at minimum, a significant reduction in research and progress in the field.

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See *Selected References* for Chapter 2.

2

Development and Use of Models

ON THE ART OF MODELING

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The problem of teaching or developing creative modeling ability is considered in the light of three basic hypotheses concerning the processes of enrichment (elaboration of very simple models), association (analogy with previously developed structures), and alternating attention to different aspects of the task. Based on these hypotheses, specific steps are presented which have been developed to help individuals acquire modeling skills. The steps are illustrated by means of an example. Other sources of modeling ability are also suggested.

The discussion focuses on specific hypotheses concerning the differences between the *teaching of models* and the *teaching of modeling*.

Intuition in Modeling

The process by which the experienced management scientist arrives at a model of the phenomenon he is studying is probably best described as intuitive. The term "intuitive" refers here to thinking which the subject is unable or unwilling to verbalize. Indeed, really effective experienced persons in any field typically operate in a largely intuitive manner and view with impatience attempts to make their methods explicit. The experienced management scientist may well consider questions as to how he selected the variables to be included in the model, how he decided which were to be regarded as random, and

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so on as so trivial that they cannot occupy his serious attention or so nontrivial that they cannot be answered. He is perhaps willing to regard the abstraction and translation of a management problem into a scientific problem as an art in the sense that it must remain largely intuitive. Any set or rules for obtaining models could have only the most limited usefulness at best, and at worst, might seriously impede the development of the required intuition.

If one grants that modeling is and, for greatest effectiveness, probably ought to be an intuitive process for the experienced, then the interesting question becomes the pedagogical problem of how to develop this intuition (2). What can be done for the inexperienced person who wishes to progress as quickly as he can toward a high level of intuitive effectiveness in management science? What can be done for the experienced person whose mind "draws a blank" when seeking to model some management problem? Can we say only, "Get more experience, for it is the chief source of intuitive development and the only recourse when intuition fails?" In what follows, an effort is made to verbalize about the process of developing models in a very limited fashion and to consider the role of such verbalizations in the educational process. In attempting to make the process of modeling explicit, it may be reasonable to suppose that one is raising hypotheses about the process and that one is providing a possible target for imitation when intuition is insufficiently developed. It does not appear reasonable, however, to suppose that one could provide a general "recipe" for making models, not that one could do very much more than modestly enhance the process of developing intuition. It may well be that intuition or artistic skill is largely the product of imitation and practice, yet this process of development must have a beginning. Experience suggests that this beginning must include more than simply a familiarity with other people's models.

Justification and Discovery

A basic distinction that must be communicated to the inexperienced is the difference between the "context of justification" and the "context of discovery" (4). Management science (and all science) is reported and communicated in the form of a logical reconstruction which aims at providing a justification for the inferences produced. This logical reconstruction has little if anything to do with the psychological process by which the inferences were first obtained. It is the custom in science to report a piece of work by stating the assumptions of premises which determine the model, showing the deductive steps by which the relevant consequences of the model were obtained, and then reporting the design and analysis of the experiment aimed at testing the hypotheses suggested by the consequences of the model. All this is very much *ad hoc*. The danger for the inexperienced is that, finding little else in the literature of their science other than such justification, they will begin to assume that this is a description of the process of discovery.

The experienced scientist knows that the psychological process is very different, but he seldom attempts to verbalize it. One may wonder, however, whether even those with considerable experience do not sometimes practice a little delusion of themselves and their colleagues by tending to read *ad hoc* justifications as descriptions of the context of discovery. One often senses that a writer is implicitly saying, "See how logical,

how methodical, how brilliantly inevitable was our progress in this study." Since all of the writing in a science is likely to be of this sort, one must conclude that the experienced persons in a field are not of great help to the inexperienced, so far as the art of modeling is concerned. In fact, the inexperienced may be led far astray if they begin to imitate the logical process in seeking to develop their own intuitive skill. It is not at all clear that the teaching of models by exposing the inexperienced to the *ad hoc* contributes much to the development of creative model building ability. Indeed, this is the fundamental criticism that might be made of management science education. The teaching of modeling is not the same as the teaching of models. How then, is one to teach modeling?

Skill in modeling certainly involves a sensitive and selective perception of management situations. This, in turn, depends on the sort of conceptual structures one has available with which to bring some order out of the perceptual confusion. Models can play the role of giving structure to experience. Yet we seldom encounter a model which is already available in fully satisfactory form for a given management situation, and the need for creative development or modification is almost universally experienced in management science.

Three Basic Hypotheses

The approach to the development of model building skill which we have explored might be stated in the form of three basic hypotheses. It is of some importance to regard these statements as hypotheses, since no really systematic test of their effectiveness has been made.

The process of model development may be usefully viewed as a process of *enrichment* or *elaboration.* One begins with very simple models, quite distinct from reality, and attempts to move in evolutionary fashion toward more elaborate models which more nearly reflect the complexity of the actual management situation.

This seems harmless enough, yet it is of some importance to point it out explicitly to the inexperienced. The attempt to begin immediately with a rather rich model may become a serious source of frustration. Starting simply gets things moving and, thus, tends to relieve some of the tension. It does, however, require a certain amount of poise or "guts" to back off from a complicated problem and begin with a simple conceptual structure. It requires one to deliberately omit and distort certain aspects of the situation and to knowingly commit the sins of suppressing difficult considerations and suboptimizing.

Analogy or *association* with previously well-developed logical structures plays an important role in the determination of the starting point of this process of elaboration or enrichment.

Clearly, one point of teaching models is to provide such well-developed logical structures which can be utilized more or less directly as starting points. It must be emphasized, however, that they typically provide only the starting points. When one asks if a given management situation can be modeled in the framework of linear programming or waiting line theory or inventory theory, what is really being asked is whether one of these structures will give a head start in the evolutionary process of obtaining a useful model. Sometimes the search for analogy calls forth broad general structures such as differential equations or probability theory, some-

times more specific and highly developed structures like waiting line theory, and sometimes very specific models developed especially for another management problem. While analogies are central to management science, we are concerned here with what steps should be taken subsequent to the discovery of such an association or when none appears possible. This is perhaps another way of saying that management science is an emergent science and a long way from handbook engineering, which uses "off the shelf" models.

The process of elaboration or enrichment involves at least two sorts of *looping* or *alternation procedures*.

1. The alternation between modification of the model and confrontation by the data. As each version of the model is tested, a new version is produced which leads in turn to a subsequent test.
2. The alternation between exploration of the deductive tractability of the model and the assumptions which characterize it. If a version of the model is tractable in the sense of permitting the attainment of the analyst's deductive objectives, he may seek further enrichment or complication of the assumptions. If the model is not tractable or cannot be "solved," he returns to purify and simplify his assumptions.

The importance of the first of these looping procedures is to make clear that the research need not be conceived as one grand test of a single model. Nor need one decide whether to develop the model first or "get the data" first. It is of considerable consequence in management science to note that a part of the data consists of the attitudes of the client, not only toward the management situation being studied but toward the management scientist studying it. The role of looping here has been previously explored (3).

The second of these alternations is the central concern of this discussion. Indeed, facility in modeling means, to a large extent, the selection and modification of basic assumptions which characterize models. Here again a certain poise is required to work with a variety of assumptions, some of which are more nearly in agreement with the analyst's conception of the management problem, while others may be productive of models more tractable from the viewpoint of his deductive abilities. The task is to discover a set of assumptions which are both usefully descriptive of the problem and deductively tractable. Implicit in this sort of proposition is the refusal to resort to simulation until a serious attempt at analysis has been made.

Whatever the relevance of these hypotheses for particular scientists, it has been our impression that conveying to the inexperienced the notion that modeling is a process with some such looping dynamics is essential. In the following section, the illustration of this in a particular instance is suggested.

Some Specific Hypotheses

In the process of attempting to develop modeling ability in inexperienced persons for a number of years, several specific suggestions have emerged. We regard these as hypotheses in the sense that no claims can really be made as to their general effectiveness. In situations where persons are very inexperienced, these suggestions appear to be helpful. At least they are better than no explicit remarks whatsoever about procedure, since they do prevent the inexperienced from being completely at a loss as to how to respond to the challenge of developing a model.

In presenting these hypotheses in the

context of an example, it is natural to choose an example which furnishes a good illustration of the ideas, but in doing so one once again introduces something of the flavor of an *ad hoc* reconstruction. Clearly, things will not always work out as in the example, and, thus, the suggestions cannot be rigidly interpreted or applied.

Suppose one undertakes the problem of designing a transportation system which is to serve a network of terminals on a fixed schedule. The locations of the terminals are known and some data are available or could be obtained on the time pattern of demand for transportation among the terminals. We suppose also that the criterion for a good design involves some measure of service furnished in response to the demands, combined with some measure of the cost of obtaining and operating the equipment to be used in the system. Clearly, considerable effort may be involved in bringing the study to this point of definition, and there are well-known difficulties with making operational the criterion for a good system design. We will, however, suppress these considerations in order to emphasize the model building aspects of the study. We suppose that it becomes clear to the designer that he may determine the schedule of arrivals and departures to be specified by the timetable and the number of vehicles to be available for running out the timetable. He may attempt to produce directly a model which will predict the level of service, investment, and operating costs for any choice of timetable and number of vehicles. He may search for analogies to this problem among the well-developed logical structures with which he is familiar. Suppose, however, that this effort is unsuccessful and that he seeks to factor the system design problem into simpler problems for which models may be more readily obtainable. This is our first suggestion or hypothesis.

Factor the System Problem into Simpler Problems

In this example the analyst might decide to consider:

1. The schedule design problem: Given a fixed fleet of vehicles, what schedule of arrivals and departures will give the highest level of service and still be within the capabilities of the available fleet?
2. The fleet size problem: If a schedule of arrivals and departures is given, what is the minimum fleet size which can accomplish it? (We have already allowed the assumption of homogeneous vehicles to creep in.)

An ideal factoring of the system design problems would yield simpler problems which could be modeled and would subsequently permit easy combination into a system model. When factoring occurs, the result is several problems whose solutions are suboptimal or approximate from the viewpoint of the system model. For the inexperienced, this deliberate setting aside of the ultimate design objectives is often a very difficult step. Having done it, however, one may attack the simpler problems, for example, the fleet size problem.

Establish a Clear Statement of the Deductive Objectives

An essential early step would appear to be the achievement of a clear (but still tentative) statement of the deductive objective of the model. Do we want the model to predict the consequences of various policies? Do we want it to suggest an optimal policy? In the fleet size problem, suppose we take the deductive objective to be simply the determination of the minimum fleet size

which can accomplish a given schedule of arrivals and departures. Such a statement provides the criterion for determining the deductive viability or tractability of the model. Yet in establishing such an objective, one should keep open the possibility that it may prove unachievable, or that different objectives may suggest themselves as the model is developed. The final deductive objective may be foreseen in advance, or it may emerge as a surprising result of the study of the model.

Seek Analogies

At this stage, as well as at any other stage in the process, one should seek opportunities to make analogies between the problem at hand and some previously well-developed logical structure. These analogies will often occur as a sort of intuitive leap. Is the problem a linear programming problem, a queuing problem, or an inventory problem? Is it usefully similar to one which has been modeled by someone else? Note that the possibility of an analogy ought to be considered even before the problem is very well defined, since analogies may well suggest the way in which the problem might tentatively be made more specific. We will suppose that the fleet size problem does not yield immediately to this search for analogies and it becomes necessary to take further steps.

We do not wish to give the impression here that the process of discovering analogies is easy or well understood, but only to suggest that it may be helpful to be somewhat self-conscious about it.

Consider a Specific Numerical Instance of the Problem

This is a key step for the inexperienced person. The specification of a simple instance of the problem is often difficult for the beginner, since it represents a retreat (hopefully temporary) from the generality and complexity which he ultimately seeks. The purposes of the specific example are at least three:

1. To lead the analyst to make statements about the assumptions which characterize the example. It is these assumptions which may be a useful starting point for achieving greater generality.
2. If the numerical instance can be "solved" by inspection, then perhaps the process of solution can simply be generalized.
3. The specific instance provides a workable starting point for establishing a symbolism and giving general expression to some of the obvious things which are noticed in the specific case.

Suppose for example, we consider a network consisting of terminals numbered 1, 2, and 3, which is to be served according to a timetable specified below. The timetable is based on an eight hour clock and repeats every eight hours.

Departure times from Terminal 1: 2, 5, 8
" " " " 2: 1, 3, 7
" " " " 3: 1, 4, 7

The routings are given as: 1 to 2, 2 to 3, 3 to 1, and the running times on these routes are 2 hours, 1 hour, and 2 hours, respectively. This permits the construction of the complete timetable:

Terminal 1

Arrivals	Departures
1	2
3	5
6	8

Terminal 2

Arrivals	Departures
2	1
4	3
7	7

Terminal 3

Arrivals	Departures
2	1
4	4
8	7

At this point one might discover by "inspection" or by "trial and error" that this timetable can be run out with a minimum of four vehicles. By asking how such a result was obtained and then generalizing, one may find the key to a workable model for the problem. If this fails, however, the example provides a basis for making some explicit statements about the assumptions which it implies. For example, we seem to be assuming:

1. That the schedule must be met. No deviations from the specified departure times are permitted.
2. That the running times are inclusive in the sense that they include the times for a vehicle to load and unload.
3. That the running times are invariant. The possibility of breakdowns or delays is suppressed.
4. That the number of arrivals and departures at each terminal will be equal during each scheduling period.

Perhaps there are other assumptions as well, but these begin to define the sort of problem which has been established. If we fail to achieve the desired result with these assumptions, we can come back and modify or relax some of them for another try. In this sense, the assumptions that an analyst presents first in a journal article were probably actually discovered last—as he did the work. The task is to discover a set of assumptions which lead to a tractable model, and to do this typically requires a number of attempts.

Establish Some Symbols

Perhaps the next step might be to translate the numerical example into symbolic terms. For some reason this is often a difficult step. One wants to choose symbols which are suggestive of their interpretations and to give careful definitions of each. The beginner often fails here, and carelessness at this point has serious consequences later on.

Suppose, for example, we elect the rather conventional double subscript notation. Let:

a_{ij} = the time of the ith arrival at terminal j

d_{ij} = the time of the ith departure from terminal j.

Now we are at a crucial point. What to do next? We suggest that in the absence of any useful insight, one simply writes down in symbolic terms some of the obvious things which can be seen in the numerical example. Our hypothesis is that giving expression to the obvious will be highly suggestive in terms of further steps in the development of the model.

Write Down the Obvious

What we have in mind are such things as conservation laws, input-output relations, ideas expressed in the assumptions, or the consequences of trivially simple policies. In the fleet size example, we might simply try to express the basic conservation law which states that the vehicles provided will spend their time either in making runs between terminals or sitting idle while waiting to depart. If we have a fleet of k vehicles available each scheduling period, we provide an input of kT vehicle hours, where T is the length of the period. These vehicle-hours will be devoted to either idleness (let I = total vehicle-hours of idleness) or running (let R = the total vehicle-hours of running). Thus the conservation law is

$$kT = I + R.$$

Hopefully, such a simple statement will

be suggestive. Perhaps in this case we notice that R is fixed by the specification of the timetable, and that to minimize k one must minimize I. What can one do to influence the amount of idle time? Since idle time is generated when a vehicle waits at a terminal for its scheduled departure, it must be that the way in which arriving vehicles are assigned to departures will influence idle time. At terminal 1, we might make the following matching of arrivals and departure times.

Vehicle Arriving at	*Departs at*	*Idle Time*
1	2	1
3	5	2
6	8	2

This matching generates a total of five vehicle hours of idle time.

Before proceeding, it is worthwhile noticing a very important property of this system. So long as departure times are met, nothing which is done at one terminal can influence the idle time at the other terminals. This means the system can be "cut" in the sense that we can minimize idle time terminal by terminal, rather than having to consider the entire system at once. In symbolic terms the idle time at terminal j, I_j, is independent of the idle time at terminal k, I_k, and the idle time for the system is given by

$$I = I_1 + I_2 + I_3.$$

The real objective of systems analysis is not simply to study larger and larger problems, but to find ways of "cutting" large problems into small ones, such that the solutions of the small ones can be combined in some easy way to yield solutions for the large ones.

Using the numerical example, one might try some other matchings of arrivals with departures. We notice that if at any time more departures have been scheduled than there have been arrivals, the excess departures will have to be made by vehicles kept over from the previous scheduling period. One can easily write out all of the possible matchings and note that a matching which keeps no vehicles over from the previous period generates five vehicle-hours of idle time; one which keeps one vehicle over generates 13 vehicle-hours of idle time; one which keeps two over generates 21 vehicle-hours of idle time, and so on. Thus, keeping down idle time seems to be associated with keeping down the number of vehicles kept over from the previous period.

Now this same insight can be expressed symbolically.

$$I_j = \sum_i d_{ij} - \sum_i a_{ij} + A_j T.$$

Here A_j is the number of vehicles kept over from one scheduling period to the next at terminal j. At this point the problem is "solved" in the sense that the minimum fleet size will result when we have minimized the A_j. Further examination of the numerical example may suggest that the A_j will be minimized when arriving vehicles are assigned to departures on a first-in-first-out basis. (There may be other policies which are as good, but there are none better than FIFO.)

All that remains is to compute the minimum fleet size. We may again return to the numerical example to compute the running time generated by the schedule. Using our symbolism, we might express this computation as:

$$R = \sum_i \sum_j a_{ij} - \sum_i \sum_j d_{ij} + BT.$$

Here B is the number of vehicles that depart in one scheduling period and arrive in the next.

Now the symbolism and the expression we have established begin to yield some interesting deductive consequences. It turns out that

$$kT = I + R = \sum_j I_j + R$$
$$= \sum_j A_j T + BT$$

and thus

$$k = \sum_j A_j + B.$$

Thus we can suggest, "Find the minimum number of vehicles which must be kept over at each terminal, using a FIFO assignment policy. Add to the sum of these minima the number of vehicles which are on route at the end of a scheduling period, and the result will be the minimum fleet size." This result was originally obtained by Bartlett (1).

If we had not been successful, perhaps the next step would have been to return to the numerical example or to the assumptions, looking for ways to simplify and try again. As it is, we might wish to go on toward enriching or complicating the model.

If a Tractable Model Is Obtained, Enrich It. Otherwise, Simplify

One might, in our example, wish to consider different types of vehicles, running times which are random variables, schedules which change from period to period, breakdown and maintenance time for the vehicles, and so on.

Generally speaking, one may simplify by:

1. Making variables into constants
2. Eliminating variables
3. Using linear relations
4. Adding stronger assumptions and restrictions
5. Suppressing randomness

Enrichment may involve just the opposite sort of modification.

Other Sources of Modeling Skill

Sensitivity to certain other ideas appears also to be associated with the achievement of facility in modeling. For example, it is obvious that a feeling of being at ease with mathematics is important. One of the reasons that one studies advanced mathematics that will probably not be "useful" is to achieve a more comfortable and relaxed grasp of less advanced mathematics which is likely to be used. Some appreciation of the various purpose which models may serve is helpful. Illustrating the use of models to give quantitative predictions, to give qualitative predictions, as data collection plans, as research plans, as perceptual sensitizers, as devices for structuring knowledge, and so on tends to broaden one's view of the sorts of models which are worth developing and the different directions their development might take.

Similarly, attempts to develop a consciousness of some of the characteristics of models appear helpful. Beyond the rough description of a model as "simple" or "complex," one might usefully consider:

1. *Relatedness.* How many previously known theorems or results does the model bring to bear upon the problem?
2. *Transparency.* How obvious is the interpretation of the model? How immediate is its intuitive confirmation?
3. *Robustness.* How sensitive is the model to changes in the assumptions which characterize it?
4. *Fertility.* How rich is the variety of deductive consequences which the model produces?
5. *Ease of Enrichment.* What difficulties are presented by attempts to enrich and elaborate the model in various directions?

Conclusion

The test of such hypotheses as these is, of course, whether they appear to enhance model building skills. In making such an investigation, it is important

to present the model building challenge or opportunity outside of any context which prejudices the result in an obvious way. Problems which are presented at the end of an extended discussion of some particular logical structure do not present the same kind of challenge as problems encountered outside of any such context. Similarly, exercises which require one to substitute numbers in previously developed models may help to bring familiarity with the models, but they do not help to develop model creating ability. A much more useful introductory device is to present a simple model and ask for enrichments in specific directions.

The central points, however, are that the teaching of models is not equivalent to the teaching of modeling and that there is a difference between the context of justification and the context of discovery. We have attempted to raise here the hypothesis that some explicit suggestions can enhance the process of developing the intuitive skill associated with model building.

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COMPUTER SIMULATION: A SOLUTION TECHNIQUE FOR MANAGEMENT PROBLEMS

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Computer simulation can provide a suitable methodology for studying business system behavior under a variety of assumed conditions. It also provides a means of analyzing the simultaneous interaction of many system variables to yield valuable managerial insights. Many successful simulation applications have involved physical systems; however, the technique is being applied increasingly to a broader class of problems, e.g., the study of the behavior of business systems.

Although computers are currently being used primarily for rapid processing of data, there is little doubt that computer-processed information will be a requirement in providing management with timely and accurate data for evaluation, analysis, and as an aid in decision making. At the top management level, decisions are concerned with directing the organization and providing means of assuring its survival. To achieve maximum effectiveness at the operating level, plans and policies must be applied to the available resources, subject to specified constraints and risks. However, there is generally insufficient information for these decisions, and they often cannot be structured as a set of procedures. But, most important, policy decisions are based on a blend of intuition, experience, and emotion.

Looking more specifically at the management control process, measurement, reporting, evaluation, decision rules, and feedback are susceptible to computer processing. However, the decision criteria, plans, and objectives are still subject to human judgment. At the operating level, where the physical processes in a system are applied, there is the highest opportunity for computer application. Numerous examples exist of automated data processing, essentially in production and inventory control and accounting. Examples of decision rules applied to physical processes can be found in the *Journal of Operations Research, Management Science,* and *Journal of Industrial Engineering.* The interesting fact, however, is that in all of these instances of automated data processing, supervisors are still required to deal with the workmen who actually operate the processes. Specific data processing activities can be and have been automated, yet management still performs the basic decision functions.

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The Use of Computer Simulation

In view of the intricately complex nature of large business systems, it is difficult to evaluate new management concept or system designs. Direct experimentation poses almost insurmountable problems due to disruptions, uncontrolled results, length of time

required, and possibility of costly mistakes. Computer simulation, on the other hand, has been shown to provide a suitable methodology to study business system behavior under a variety of conditions and to provide a means for analysis of simultaneous interaction of the many system variables to yield valuable insights. In view of its capability of rapid interrogation of system performance, simulation is becoming an integral part of "real time systems" (25).

Computer simulation can be considered as an attempt to model the behavior of a system in order to study its reaction to specific changes. The simulation model is seldom an exact analogue of an actual system. Rather, it is an approximation of continuous time dependent activity. If the properties and elements of the system are properly defined, then the tracing through by the computer of the simultaneous interaction of a large number of variables provides the basis for studying system behavior. A model of the system indicates relationships which are often otherwise not obvious and has the capability of predicting system behavior which results from changes in system design or use of alternate decision rules.

For many years engineers have used scaled models to simulate system response. The armed forces have used exact duplicates of operating systems for training. There have been laboratory studies which can be considered similitude or an attempt to duplicate reality in a laboratory environment. This has been extended to the use of management games where people interact with the output of a computer and make decisions on information received. Computer simulation has been directed toward the use of models of the behavior of a system so that the results correspond to the problem being studied. Abstract mathematical models, on the other hand, are used for problems which correspond with reality to a sufficient degree to produce useful solutions.

Not only has simulation increased in use as a means for studying and understanding new problem areas, but it has a number of distinct advantages. Once a simulation model is completed, the time for experimentation is considerably reduced. The cost of simulation models is now being reduced to the point where for larger problems it is an extremely economical tool. The fact that all the work is done in a computer rather than a laboratory or actual operating environment provides better experimental design and control. The ability to explain the simulation model in terms of a real problem is a far more useful tool than some of the analytic techniques which cannot be described to management or the potential user.

Problems in Simulation

Although simulation has many advantages, one should not overlook the difficulty involved in developing a model, programming it on a computer, and utilizing the results. Although computer simulation has been used for a number of years, there are still many pitfalls that must be avoided. One of the greatest difficulties is that of developing a suitable model. Another is the use of computers in the simulation process which poses a number of problems, including computer programming, search techniques, data storage and retrieval, function generators, etc. The computer programming problem has in many instances proven to be a major stumbling block.

In recent years there have been a number of approaches taken to minimize the programming problem. One is

the development of models to study a specific area, such as Job Shop Simulation (27). Using this type model, the user is required to provide appropriate data and a description of the facility to be studied, and the computer program needs little modification. A similar approach has been taken in the Gordon General Purpose Simulator (11). A somewhat more general approach to this problem has been tackled by the use of the DYNAMO Compiler (9), in which a set of equations is submitted to the computer which, in turn, compiles these and generates a computer program. Therefore, once the model is completed, no further programming is required. As an alternative to writing directly in machine language, a simulation language has been developed called Simscript (19). Once the model is written, no further programming is required. The Simscript language has all the flexibility of computing language but much of the simplicity of a special purpose approach. Quickscript (30) and programming by questionnaire (10) are extensions of this approach to developing useful simulation languages. Thus, depending on the type of problem being undertaken, it is possible to use a variety of approaches to obtain a computer program. Several of the computer manufacturers have developed standard programs which are readily available and require no further computer programming effort (18).

A second problem is in the area of experimental design. Considerable effort is often expended in an attempt to obtain information and is often done in an inefficient manner based upon poor input data. It is therefore necessary to consider computer simulation as an equivalent to a laboratory experiment. Before any simulation is undertaken, areas of payoff or urgency should be established and the feasibility of completion of the project with estimates and budgets should be provided. When defining the problem, there should be careful observations and correct statements concerning what is being studied and discussions held with experienced personnel. Preliminary approaches or brainstorming should be undertaken in order to attempt to define solutions to the problems being studied. Organization of the data, the use of sample vs. exhaustive representation, and the use of statistically designed experiments should all be incorporated. This becomes particularly important when trying to state on a rigorous basis the comparison of one system design to another. Simply because a problem is run on a computer does not mean it is either valid or statistically significant.

A number of fairly significant techniques have been developed for analysis and evaluation of data (8). Some of these are referred to as "Monte Carlo sampling" or "importance sampling." In these techniques the data are handled in such a way as to minimize the amount of data required and to maximize the information that can be derived from the manipulation of the data. In many applications the use of analysis of variance or regression anlysis is very important. It is necessary in evaluating the results of a simulation to have the appropriate criteria and measures of system performance. These, of course, do not depend on the simulation but rather on the user.

The problem of modeling is important since the results of simulation are no better than the model used. A model provides a formal statement of system behavior in symbolic or mathematical form. The model should be constructed so that the parameters, variables, and forcing functions correspond to the actual system. The parameters should include properties which are sufficient to define the behavior of the system; whereas the variables are the quantities

which describe the behavior for a given set of parameters. The forcing function provides the stimulus, external to the system, which causes the system to react. For example, job orders which enter a production system cause men to work, machines to run, queues to form, etc. In this way, job orders become the forcing function for the system. Whatever particular form is used, a model provides the frame of reference within which the problem is considered.

A model need not duplicate actual conditions to be useful. The model should be designed to predict actual behavior resulting from changes in system design or application of new decision rules. Prediction implies an understanding of the manner in which the system reacts, that is, being able to specify the outputs for a given set of inputs.

Models are merely the basis for testing new ideas and should not become ends in themselves. The simpler the model, the more effective for simulation purposes. Tests should be made prior to model building to determine the sensitivity of the characteristics which are incorporated. Typically, certain key characteristics contribute the majority of the information to be derived from simulation. Other characteristics, although more numerous, do not contribute much to the final system design. In this sense, simulation can be considered as sampling the reaction of a system to a new design. It is imperative, therefore, that a representative sample be taken, rather than an exhaustive sample. Thus, the number and type of characteristics to be included should be carefully selected (24).

The major task of simulation is reached at this point. A logical model which is merely descriptive is not suitable for computer simulation. The model must be modified to suit the particular computer on which it will be programmed. Factors such as kind of memory, speed of computation, and errors due to rounding must all be taken into account. Simplification is often necessary due to speed of computation or limitation of the computer memory. Methods of filing information and representing time are also significant problems. Which data to accumulate and at what point in time often are difficult to decide beforehand. Thus, the program must be flexible and easy to change.

As computer programming proceeds, there is generally feedback which provides the basis for further modification of the model. At the outset, the decision must be made whether to make the program general or special purpose. The type of programming changes radically, depending upon the end use of simulation. Modular programming, which treats each section independently, provides flexibility at a small cost in computation time and storage. In view of the many logical relations which exist in systems, computer programming represents an important aspect of the problem.

Successful Applications of Simulation in Management Problems

A considerable body of literature exists covering the use of simulation in various applications (1, 2, 17). As shown in Figure 1, simulation should

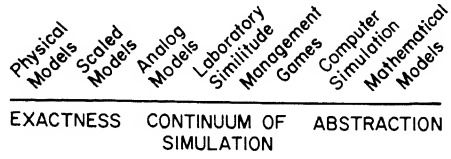


Figure 1

be thought of as a continuum, starting with exact models or replications of reality at one extreme, with completely abstract mathematical models at the other. When viewed in this manner, the breadth of simulation can be appreciated.

The wide variety of simulation applications is somewhat astounding. Not only has simulation been extremely successful for purposes of studying physical systems but it has been used for such diverse applications as the study of personality (29), election results, and gross economic behavior. In order to evaluate where simulation is most effective, it is probably best to categorize problems as involving physical and nonphysical systems with high and low risk decision alternatives.

As shown in Figure 2, the area for

	High Risk Poor Data	Low Risk Good Data
Physical Systems	Fair Results	Excellent Results
Non-physical Systems	Bad Results	Poor Results

Figure 2

Probable success of simulation application

greatest success is physical problems having very low risks. The poorest applications are nonphysical problems having high risk or little data. This situation may change as the simulation technique is applied to a broader class of problems.

A review of the literature indicates many successful applications of simulation in business (7, 15, 20, 21, 28). A publication *Simulation-Management's Laboratory* (14), based on a fairly extensive survey of simulation applications, shows the applicability to a wide variety of management problems. Some of the applications include:

Company	*Management Decision Area Simulated*
1. Large Paper Company	Complete order analysis
2. U. S. Army Signal Supply	Inventory decisions
3. Sugar Company	Production, inventory, distribution
4. British Iron and Steel	Steelworks melting operation
5. General Electric	Job shop scheduling
6. Standard Oil of California	Complete refinery operation
7. Thompson Products	Inventory decisions
8. Eli Lilly & Co.	Production and inventory decisions
9. E. I. DuPont	Distribution and warehouse
10. Bank of America	Delinquent loans

In a survey by Malcolm (16), the following applications are described:

Company	*Problem Simulated*
1. Eastman Kodak	Equipment redesign, operating crews
2. General Electric	Production scheduling, inventory control
3. Imperial Oil	Distribution, inventory
4. United Airlines	Customer service, maintenance
5. Port Authority of New York	Bus terminal design
6. Humble Oil	Tanker scheduling
7. U. S. Steel	Steel flow problems
8. IBM	Marketing, inventory, scheduling
9. SDC	SAGE Air Defense
10. Matson	Cargo transportation

These lists are not meant to be all-inclusive but rather indicate the variety and type of problems that have been solved by simulation.

The Use of Simulation for Scheduling Job Shops

Scheduling of job shops has long been considered a critical problem. Extensive work using analytic techniques to find a suitable solution was tried. However, in view of the large-scale combinatorial nature of this problem, no solution was found except for extremely small cases. Extensive models have been developed over a period of years and have evolved into what today is known as the Job Shop Simulator. Although the computer program cost a large sum of money and took almost two years to develop, the Job Shop Simulator has been used successfully in a large number of companies. Notably, it has become an integral part of the manufacturing function at General Electric and has been used extensively in many other companies, including the Hughes Aircraft Company (13).

The kinds of decisions that can be aided by the use of this type of simulation are the following:

1. Establishing required capacity in terms of equipment, facilities, and manpower in order to meet unpredictable customer demand
2. Examination of alternative types of demands and the capability of the system to respond
3. Examination of the inventory problem relating equipment utilization to cash requirements and customer demand (It is possible to meet customer demand by maintaining large inventories.)
4. Development of appropriate scheduling decision rules to maintain a minimum inventory and meet specified delivery requirements
5. Study[ing] the operation of a physical facility through the appropriate use of forecasting techniques, load level techniques, scheduling decision rules, and priority decision rules

In addition to specific decision areas, there is the information generated from the simulation which provides the basis for feedback on performance so that management can make decisions on the number of shifts to run, need for additional equipment or capacity, or amount of cash to maintain for adequate inventory. The use of this particular program has been extended to an operational system at the Hughes Aircraft Company for real time manufacturing control. The Job Shop Simulator was first used to examine alternative scheduling decision rules. These rules, in turn, provided the basis for developing a supplemental computer program which is used to generate the factory job order status on a daily basis. This computer program, by application of priority decision rules, is used to generate new priority lists each day, taking into account all occurrences for the given day. Thus, the system operates on essentially a daily cycle with all information current and correct as of that point in time. This type of real time application appears to offer considerable opportunity for the use of simulation in industry (6, 23).

Studying Business System Behavior

Considerable effort has been extended to develop models of the total business system. Several efforts along these lines have been undertaken at SDC (12), Stanford Research Institute (4), IBM Corporation (5), and M.I.T. (22). A notable example of work being under-

taken in this area is by the Industrial Dynamics Group at M.I.T., which is concerned with studying total system behavior. The basic premise of this latter simulation is that the dynamic interaction of system variables and information feedback leads to amplification, oscillation, and delays in system performance. The behavior of a system, then, is the result of desired objectives and the decision rules employed to carry out these objectives. Thus, where there is an attempt to make corections and adjustments in flow rates, there is the possibility of delays or amplification, or there may be conflicts between short- and long-term objectives. Forrester in his book on industrial dynamics [see (9) in References] describes a number of studies that have been undertaken and describes future studies of total management systems.

In providing the means for experimenting with a total business system, a quantitative formulation of the various behavioral characteristics, component interdependencies, system flows, and stochastic functions is required. The formulation is used to develop a simulation program which can trace the activities of the system as they change in time. In this way, a large number of variables can be examined simultaneously, without explicit knowledge of their interdependencies.

A model of a business system is concerned with a "decision network" rather than an explicit characterization of the decision maker per se. The difference stems from studying the information flow and decision rules in the system, as contrasted with studying the behavior of the individual. To the extent that a model faithfully characterizes the behavior of a given business and that suitable decision criteria can be established, a computer model can generate information useful in the study of business problems. Further, the computer is capable of providing summaries of the information generated during the simulation to permit evaluation of experimental designs or to permit useful insights on system behavior.

The characteristic behavior of decision makers in response to information provides the basis for studies concerned with organizational aspects of information flow. The density of communication linkages among decision makers provides data which could be used to establish critical decision points in a system. Further, a communication network linking the managers with the operations provides the means for establishing feedback control loops. In a sense, management is linked with the resources of the business via information flowing through a communications network. Characteristics of the information flow among managers and between the managers and the operators provides one of the basic measures of system behavior. In an actual business, much of the information generated is not pertinent to the direct operation of the business, and often informal communication channels provide useful information. In a sense, the decision maker has surveillance over a given number of decision points, which, when linked to other decision points, define the underlying operational structure of the business.

Modeling the Activities and Functions of a Business System

A schematic representation of the information flows among various functions and activities in a typical manufacturing (resource transforming) business system is shown in Figure 3.

Central to the system is the decision-communication network, which is normally thought of as the management function. The decision network is linked

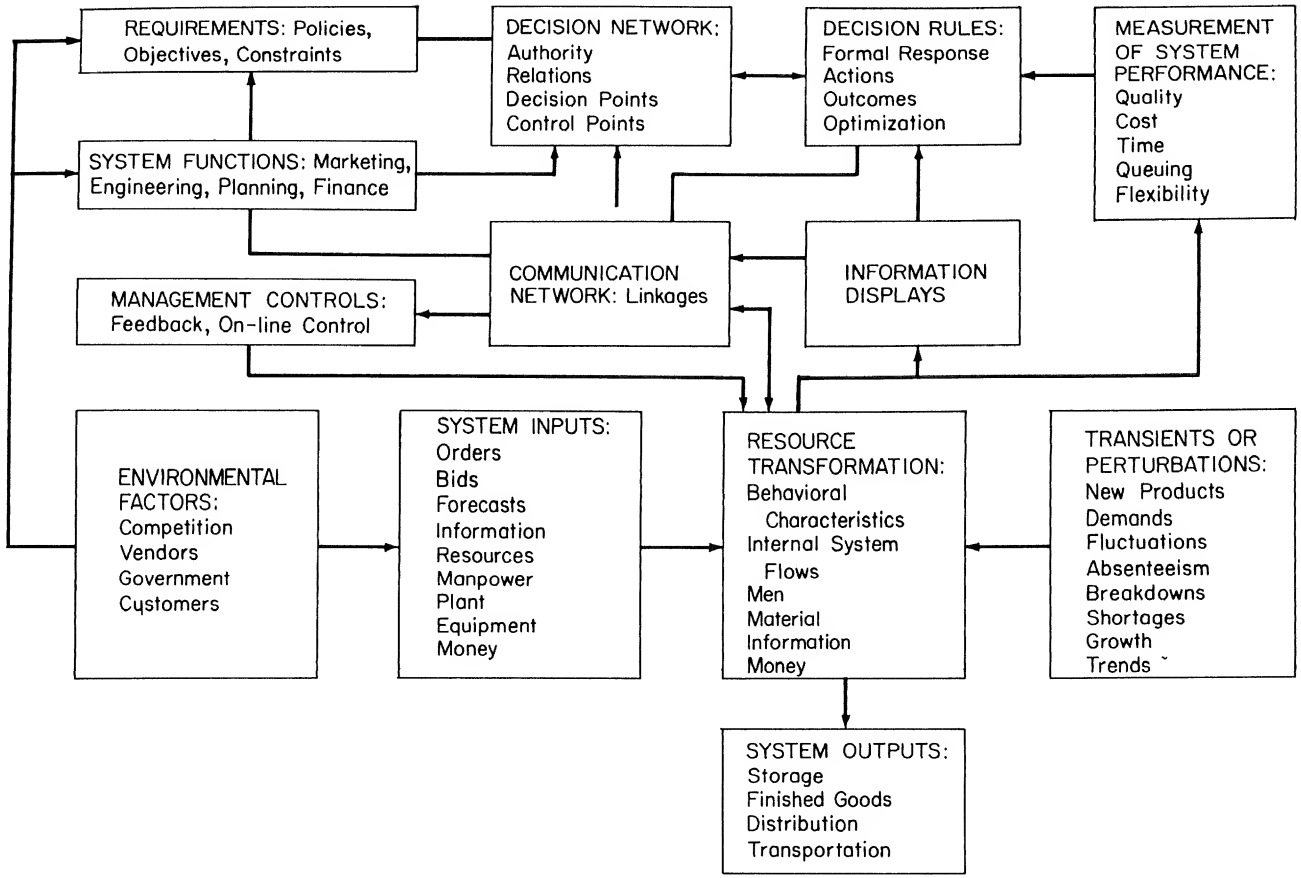


Figure 3

Activities and functions of a business system

to the resource transformation or operations subsystem through the various organizational levels. In a computer program, the simulated information generated would be used to execute the decisions in a synthetic manner. Inputs to the decision network include the system contraints or policies, system functions, and environmental factors. These too can be represented by flows of information via the communication network.

Inputs to the operations subsystems include environmental factors, customer orders, capital resources, material, etc. In addition, transients or perturbations in the operations subsystem could be used to introduce variability in performance. Outputs of the system enter distribution systems, warehouses, or finished goods storage. Although there is considerable detail associated with the operations subsystem, a computer model need merely treat the information aspects as they interact with the decision network (26).

The study of the behavior of a total system requires an explicit description of the time dependencies among the components. The primary concern in the model discussed here is the conversion of resources into goods and services. By determining appropriate strategies in relation to risks, it is possible to control rates of change of production, work force stabilization, growth rate, cost-pricing, response to demand, and the relation of income to investment.

Since computer simulation is used to trace the change in the variables across a time domain, decision rules can be made functions of the state of the variable rather than using expected values. In this respect, simulation differs from dynamic programming or gaming strategies which depend on statistical estimates as the basis for optimization. Forcing functions, which trigger the decision rules, must also be specified and are related to information flow in the system.

Since system optimization involves many variables, it is necessary to consider the many combinatorial effects. Simulation is a means for examining a large number of variables simultaneously. However, the solution is not unique but provides an estimate of the distribution of expected system performance. Thus, although all the combinations could not possibly be enumerated, sampling results tend to form relatively stable and determinable distributions.

Defining System Flows

Flows within the system can be separated into information flow (paperwork, reports, etc.), material flow, resource flow, and manpower flow. Each has its own characteristics and is therefore modeled differently.

Starting with information flow, the channels or network determines the destination of the information, and the transmission media determine the speed and message type. Information content is a function of the data, format, and timeliness. Transformation, distortion, and errors should be included, as well as the queuing effects at the decision points in the system.

Material flow has received the most attention in simulation and operations research studies. Thus, a considerable body of literature exists which could provide the basis for modeling. Reorder rules, safety stocks, value analysis, collation studies, scheduling rules, and stocking policies have been well documented. There are a number of additional considerations which might also be of interest, such as surge effects, queuing effects, interdependence of component parts, work-in-process flow rates, and resource utilization.

Resource and manpower flow are more difficult to solve, since factors external to a simulation model may have the major influence. Nonetheless, there are aspects of these factors which can be profitably studied. For example, what are the cash flow requirements in a marginally capitalized business? What is the relation between demand variation and capacity? How do capacity and capital requirements change with different products, number of shifts, skill and mobility of manpower? These and similar questions are readily susceptible to study via computer simulation.

The internal system, in addition to the basic flows, has a number of other characteristics. In particular, it is necessary to structure certain behavioral patterns such as:

1. Demand and shipping patterns
2. Value distribution among products
3. Variability in man-machine performance
4. Learning-curve effects
5. Various lead-time distributions

Rather than attempt an exhaustive description of the physical characteristics of the internal system, the considerations discussed are intended to provide some measure of the complexity and difficulty in modeling the business system.

There are a number of environmental considerations, as well as system inputs and outputs, which should also be taken into account in the modeling. The number and type of competitors, customer demands, vendor characteristics, and legal or civic factors all should be specified in developing a computer model of a business. Furthermore, forecasting of demand, gaming strategies, competitive pricing, and advertising policies are, in effect, the control of system response to variable demand. Thus, for example, maintaining standby capacity in anticipation of orders, having a complete product line, or carrying large safety stock in inventory are all means of response which are really control of the system.

From a total system viewpoint, the availability of cash affects the above considerations; that is, carrying large inventories may determine the plant capacity required or the advertising budget. In this sense, cash flow permeates all aspects of system behavior and thus affects control. Similar considerations enter into the make-or-buy question, material and tooling purchases, employment stabilization, etc. It is an explicit treatment of the many interdependencies which provides the basis for total system control.

The modeling of a total business system which incorporates the many considerations discussed would undoubtedly involve numerous details. Thus, where possible, transfer functions or aggregations should be used rather than the precise flows or system characteristics. Not only does aggregation provide considerable savings in modeling but, often more significantly, it helps reduce the size and complexity of a computer program. The modeling is, after all, designed to answer given questions or explore new areas and, therefore, should be governed by these considerations.

Conclusion

It is apparent from the many successful applications that simulation will continue to grow in importance and become a truly operational tool for management decisions. There are still a vast number of problems that can be tackled, ranging from the study of specific economic problems to total company system problems (3). Because of its many advantages and because of the need for improved techniques in

management, simulation appears as one of the most useful tools that has come on the horizon. There is still much required in the way of improved modeling, reduced cost of programming, improved outputs, etc. However, none of these problems is insurmountable, and the evidence is quite clear that there are continued improvements on all fronts. Thus, we can expect to see the use of simulation as a normal part of business operations in the not too distant future.

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HEURISTIC MODELS: MAPPING THE MAZE FOR MANAGEMENT

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An algorithm is a specific computational procedure for numerical manipulation employed in optimization models. A heuristic, in contrast, is a short-cut process of reasoning that searches for a satisfactory, rather than an optimal, solution. Heuristic approaches to problem solving are warranted when the assumptions required by rigorous optimizing techniques are either inappropriate to the problem or when the size of the problem prevents the practical application of such techniques. Heuristic programming has been used to locate warehouses, schedule truck deliveries, schedule airlines, select media schedules, and schedule the introduction of new products.

One's Business Vocabulary sounds incomplete nowadays unless liberally sprinkled with such words as *models, systems, decision theory,* and *digital computers.* As management science evolves, the two interrelated concepts of models and systems are proving their usefulness in all functional areas of business—accounting, finance, production, and marketing.

Certain aspects of the application of mathematical models to business problems are presented here, with particular emphasis on the merits of heuristic approaches as aids to decision making. The discussion is directed toward those executives and researchers who have more than just a casual or academic interest in using models and computers in problem solving and embodies considerations of reality, efficiency, and costs.

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Historical Uses of Models: Genesis and Evolution

The term "mathematical model" may be defined in two parts: Mathematics is the science of relationships—a language, the quintessence of which is conveyed and explained by numerals

and symbols. A model is the simplified representation of a concept, system, or process, and it becomes "mathematical" when expressed as a quantitative or logical relationship.

Among the earlier models developed in physics were Archimedes' law of levers, Galileo's law of the pendulum, and Newton's well-known law of gravitation—all rather simple formulations by twentieth-century standards. Upon the heels of the development of the calculus, statistical theory, and the electronic computer there has been a surge of interest in things quantitative in the business community.

The use of mathematical models has recently had a phenomenal growth in business as a means of expressing relationships between variables, testing the validity of hypotheses, and developing decision rules. The practical applications of this technology increased manyfold with the emergence of the digital computer and its capacity to "remember" large amounts of information, its perseverance in making endless calculations, its ability to consistently follow a set of programmed instructions, and its speed in retrieving and processing data.

Business models may be classified as either descriptive or normative, or both. A descriptive model is useful for portraying the behavior of a system. Most marketing simulations are of this type. A normative model is intended to be a guide to business operations, prescribing rules of operation based upon the evaluation of relevant variables and the goals of the firm.

The two types of models are not necessarily strictly dichotomous, however. For example, a simulation model not only provides an approach to *describing* and analyzing systems, but, once constructed and tested, it may be applied to *predict* the effects of alternative policies, strategies, and decisions. In this sense, the descriptive model often provides the basis for developing the normative.

A Mixed Blessing: Danger and Opportunity

That computer science has fomented a "second" industrial revolution of sorts, making possible the application of sophisticated aids for problem solving, is a mixed blessing for management. The Chinese have a word for "crisis" (*wei chi*), which is a combination of parts of the words for "danger" (*wei hsien*) and "opportunity" (*chi hui*).

The opportunities created by combining models and machines are legion and will constitute the focus of this article. Danger inheres in choosing the computer hardware, in developing appropriate models to help interpret the problem, and last, but certainly not least, in hiring the people who will develop the models and determine the quality of the output.

Closely related to the hazards posed by unqualified personnel and inadequate problem definition is the production of reams of output which covers in minute detail every aspect of the problem—print-outs of so many numbers that meaningful analysis is either impossible or extremely difficult. Although it may be necessary to examine many different dimensions while learning the problems, the ultimate goal should be to refine these into a few signposts pointing toward succinct conclusions.

Value of Simplicity: Complications vs. Simplifications

It may be easily surmised from reading the current management literature that model builders feel compelled to increase the complexity of all models on the assumption that intricacy is positively correlated with usefulness.

While this premise is valid for some systems, we believe that it is a mistake to ignore simpler approaches which frequently will serve as well or almost as well. Furthermore, elaborate models are likely to be useful only when they are the result of a long-term program of research and development.

In the exploratory stages of a problem, the elementary plotting of points is very useful and, as a first step, generally to be preferred over more mathematical methods, unless, of course, the researcher has some a priori basis for choosing specific functions. Unsophisticated methods fail to furnish clear explanations of the phenomena under investigation, but they are desirable in approaching new problems for the first time. Even the most erudite probabilistic or econometric models will yield unreliable results if employed without careful planning and consideration of the problem as well as thorough understanding of the technique of analysis.

The computer, perhaps, unfortunately has made it easy for individuals to use analytic methods that they do not understand and models that do not fit the problem. Every model that is not a reasonably true representation of reality introduces distortions, and the best safeguard against such distortions is a sound knowledge of the technique being used and its assumptions as well as experience in applying it.

What Is a Heuristic? Algorithms vs. Heuristics

To a mathematician, an "algorithm" is a specific computational procedure for numerical manipulation—a method of writing and performing any of the four basic mathematical operations. An example of a multiplication algorithm is $q \times r = s$, which may have the values of $24 \times 3 = 72$, and which may be written in a number of other forms such as $(3X)(3) = 72$, depending upon the hypothesized relationships of the multiplicand and multiplier. In finance, the formula for the present discounted value of a stream of future earnings

$$\sum_{n=0}^{\infty} \frac{1}{(1+i)^n} p(n)$$

is an algorithm. The stochastic equation

$$\hat{MS}_{i,t} = \sum_{j=1}^{K} P_{ji} MS_{j,t-1}$$

used to predict market shares in some exponential models is an algorithm. Algorithms that have played important roles in operations research include linear programming devices such as the simplex method and maximization procedures using the calculus. Whether relatively simple or extremely complex, *an algorithm guarantees optimal solutions to any complete set of data and any problem as posed by the model.*

A heuristic, in contrast to an algorithm, is a shortcut process of reasoning —in the models to be discussed here, a computerized rule-of-thumb—that searches for a *satisfactory, rather than an optimal, solution.* The heuristic, which reduces the time spent in the search for the solution of a problem, comprises a rule or a computational procedure which restricts the number of alternative solutions to a problem, based upon the analogous human trial-and-error process of reaching acceptable solutions to problems for which optimizing algorithms are not available (19).

It may not be obvious why a less precise heuristic method should be used when an algorithmic technique assures a superior solution. A good reason is that algorithms demand quantitative inputs from a clearly structured problem cast in a reasonably restrictive framework, whereas heuristics are operable in problems that are much more complex and less well structured in

terms of susceptibility to algorithmic methods. In addition, computation costs may be lower. Heuristic solutions need not be optimal to be of practical value; they need only represent some improvement in the solutions provided and the cost of application as compared with alternative methods available to management.

The activity of a digital computer when processing the flexible heuristic program closely parallels human mental activity in that it is essentially inductive in nature and may even exhibit intuition and "learning" in improving its performance by adjusting the parameters itself, provided that it is appropriately instructed in the first place (6, 19). Because it is more human than deductive in solving problems by trial-and-error procedures, the heuristic program can inspire confidence only through repeated application and when the solutions compare favorably with those derived by alternative methods of analysis. Repeated proof may be thought necessary by some simply because the "certainty" associated with a deductive algorithm is necessarily lacking.

Flexibility: Problem Defining

One of the major obstacles to developing a good model is getting a good definition of the problem. There is a risk in using an available algorithm because a researcher is likely to try to fit the problem to the familiar algorithm (for example, the linearity assumption in linear programming), especially if he knows little about the variable involved. The less the analyst knows about the situation under investigation, the more likely he is not to question the constraints imposed by the optimizing algorithms. To be sure, available heuristic routines may lead to somewhat similar problems. On the other hand, insofar as they are designed with greater flexibility, the researcher is required to choose among alternative formulations that are not available with the more restrictive algorithms.

The choice between a heuristic program and an optimizing algorithm for the solution of a specific problem must be made by comparing the error introduced into the operational decisions as a result of the algorithmic constraints in the modeling of the problem with the combined error of the suboptimality of the heuristic solution and its modeling errors. Final proof is possible only by comparing operational decisions reached via the two methods. In many problems, however, developing such final, conclusive evidence is not directly possible; thus, the vital element of managerial judgment is required to evaluate the reasonableness of the various outcomes against the reference point of empirical knowledge.

The surge of recent interest in heuristic approaches to problem solving has led to the development of computer programs designed to:

1. Schedule construction activity—smoothing materials handling and work flows
2. Manage inventory (2, 20), also performed by optimizing quadratic programming (9).
3. Balance assembly lines in automotive and electronic component plants (11, 22).
4. Schedule job shop assignments (4, 7).
5. Simulate the activities of the investment trust officer in a bank, performing evaluations that the officer could not do personally because of time limitations (3), using the General Problem Solver (15).
6. Locate warehouses (5, 13).
7. Consolidate orders for freight savings
8. Schedule local truck delivery to many small customers
9. Solve itinerary problems for traveling salesmen (10).

10. Schedule airplane timetables for airlines
11. Coordinate factors in new product introductions
12. Select media schedules
13. Discover proofs for theorems in logic and geometry
14. Design electric motors and transformers (8).
15. Lay out cutting paterns to reduce steel waste
16. Play chess (1, 14) and checkers (17).

One may deduce that the practical applications of heuristic programming are limited because it is basically more elementary than certain sophisticated mathematical approaches. On the contrary, heuristic devices are being employed with considerable success (or are in stages of development nearing use) in a number of situations by a number of companies, a few brief examples of which follow.

Locating Warehouses

The problem of warehouse locations has been considerably simplified by the use of heuristic programming, which helps to determine the locations that will be most profitable to the company by equating the marginal costs of operating the warehouses with cost savings and profit increments to be realized.

Warehouse networks are often considered from a number of viewpoints including:

1. Reducing transportation costs by permitting quantity shipments to the warehouse from the factory, rather than shipping small orders directly from factory to customers
2. Grouping products from different plants for combined shipment to individual customers
3. Speeding up deliveries to customers, which permits them to carry reduced inventories

The heuristic program considers plant location with relation to raw materials, the kind of warehouse needed (automated, intermediate transfer point, etc.), and even preferred shipping and inventory arrangements (for example, air freight costs versus inventory costs).

It also must be noted that the inventory control problem embraces considerations other than cost minimization, as employed in economic lot-size calculations. One should evaluate such problems from the profit maximization angle, considering, for example, that shipment delays may constitute costs in terms of customer good will and future orders. This frequently overlooked point illustrates the fact that canned approaches are fraught with potential errors, if the analyst fails to adjust the model to account for differences in costs, products, customers' alternatives, and so on. Warehouse cost structure is such a vital factor in pattern determination that a program used by a farm equipment manufacturer had to be recompiled and extensively modified before it could be used by a manufacturer of diversified electrical products.

Order Consolidation for Freight Savings

Traffic people work on this problem diligently, but time pressures—often allowing only thirty minutes to make a decision—make it difficult to achieve optimal solutions. The goal is minimum total cost, requiring a decision as to whether consolidation pays off. It is assumed that "to consolidate orders" implies the ability to ship over the same route, which leads to an evaluation of the cost of shipping alone versus shipping with another order. Choice is

dependent on the number of available routes and the size of the order. In most sections of the country, a maximum of four orders may be grouped, with three stop-off charges, but at least one state's laws allow six orders to be grouped. Crossing certain state lines also involves different rate structures.

Obviously, then, order consolidation poses many difficult obstacles to cost minimization. Integer programming could solve the problem, if orders numbered eleven or less, but in actual runs the optimal has been achieved only after running seven hours on the IBM 7090 computer! This problem is now being solved heuristically in a few seconds on the 7070, and the savings for a large food company may amount to as much as 8 per cent of shipping costs. (A revised version of this order-consolidation program is being set up to run routinely for another company.) Cards are read into the company's computer, with daily changing inputs, and the print-out tells which orders to group, the preferred routes to be taken, and the total costs.

Local Truck Delivery Scheduling

Linear programming is used by a number of multiproduct, multiplant companies to assign orders to particular service points and to schedule deliveries. Elements entering the calculations include demand requirements, supply capacities, and cost structures. Such programs compute the optimal allocation of resources that will minimize the total costs of production, warehousing, and transportation. Computation costs and data availability are by no means trivial considerations for the large firms, but they pose especially serious limitations to the use of such approaches by small firms.

One relatively small company uses a heuristic model for scheduling deliveries to a number of small affiliated grocers. The data used by the company include number and types of trucks available, number of customers served, time spent unloading at each customer location, distances between pairs of customers, and so on. Compared with former procedures, the heuristic scheduling device has been spectacularly successful.

The company could ill afford to pay the number of people who would be required to perform these calculations, even if it were not for consideration of prompt service to customers and opportunity costs attendant on delays. The overall savings in this case would be more predictable were it not for objections raised by the union to which the truck drivers belong, but even this constraint has not negated the overriding advantages gained through use of the heuristic search routine.

Airline Scheduling

Scheduling, a giant headache for airline management, is very similar to the familiar "tramp steamer" problem, except that planes, unlike ships, are not the same craft going out and returning. With the inauguration of the supersonic transport, the time required for loading and turnaround will become a crucial element in costs and profits. The airline heuristic of the future may well have to consider the containerization of passengers as well as of baggage and freight.

The time element is already crucial for airlines, since, for maximum efficiency, the airplanes must fly when passengers want to fly, and service requirements that vary by cities as well as competitive schedules must be evaluated. Equipment must be available, and the right aircraft must be assigned to

the right routes. Further, adding new airplanes causes major scheduling revisions. Restrictions imposed by the Civil Aeronautics Board are also decisive factors.

All of these parameters must be built into the program, making the optimizing algorithm impractical. Heuristic programming promises to be useful in developing satisfactory schedules, especially as the problems become more complicated with expanded geographical coverage, faster aircraft, changing public preferences, and the continuation of semiannual schedule changes in April and October.

Marketing

Heuristics in Marketing

Many practitioners view with suspicion the use of quantitative tools in marketing; some think such devices are worthless. The nature of the model is frequently to blame for creating such attitudes, especially when the model represents only certain facets of actuality, producing results that are inconsistent with management's empirical knowledge of marketplace realities. "Canned" or "off-the-shelf" models or computer programs—algorithmic and heuristic—are seldom appropriate for more than the preliminary exploration of marketing problems.

Although marketing analysts have been among the most vociferous critics of classical economic theory and its *ceteris paribus* assumptions, it seems that the empirical work in marketing usually centers on one independent variable at a time. Many attempts have been made to relate the effects of advertising or price changes to sales volume while essentially ignoring other concomitant variables. Repeated failures of such research to produce clear-cut operational directives have contributed to the attitude on the part of both line managers and researchers that marketing is a complex maze of behavioral mechanisms not amenable to mathematical mapping. It is not paradoxical, then, that the building of mathematical models has received a less than hearty endorsement by many in marketing.

The task of building marketing models is arduous. For instance, just to identify an adequate, minimum set of variables in terms of which the problem can be defined and then to combine these factors into behaviorally meaningful and analytically tractable expressions is difficult. One must beware in adding variables that he is not merely adding confusion by reducing the signal-to-noise ratio in the system. Further, the mere fact that variables are included does not mean that "we are taking them into account," as is often stated when defining the independent variables in regression analysis. We are trying to take them into account, but this goal is an elusive one unless the actual interactions of the variables are in accordance with our hypothetical constructs. Just because the algebraic sign is "right" does not guarantee that our assumptions are correct.

Admittedly, it is more common in marketing to find classes of models with dubious correspondence to real life—based on vague assumptions and an internal logic lacking in consistency—than to find models which approximate the interactions of supply, demand, and related marketing effort. Even the flexible heuristic is less useful in the field of marketing than in the more structured situations, mainly because it is hard to get a good model of the problem in marketing (12, 21).

Marketing Applications

Nevertheless, there are two marketing applications in which the heuristic device has proved successful. One is the scheduling of new product introduction by coordinating clerical details, planning production runs to match market needs, summarizing results, and modifying strategy. Another is media selection, involving the development of schedules according to market characteristics and evaluation of such factors as the trade-off of placing advertisements on Saturday versus scheduling them on the major shopping days of Thursday and Friday. Given the constraints in these two classes of problems, the computer searches for better allocation as it juggles the inputs and evaluates thousands of alternatives in minutes, greatly reducing the time needed to arrive at the decisions.

Optimizing algorithms have proved popular in selecting media where reach and frequency constitute the major constraints in the decision process. However, although numerical data play a major role in media selection, the "creative function" of individual judgment and skill is a principal factor (18).

Since the creative aspects are largely qualitative in essence, the heuristic program will grow in popularity as an aid to media selection because its flexible nature permits the inclusion of symbolic terms neither amenable to expression as numerical variables or scalar and vector quantities nor specifiable in terms of profit maximization or cost minimization (17).

Although new product introduction and media selection are two classes of problems that will be increasingly aided by heuristics, they can be accurately solved only to the extent that the computer is told how customers behave, which brings us full circle to the prerequisite that the problem must be learned in order to build suitable models. It is easy to develop simulation models if they are not expected to simulate very well. But if one intends to fit the variables in a meaningful way, then market simulations cannot be built in a day.

Constructing a realistic computer simulation of a market will continue to be extremely involved and painstaking. It is often helpful to break down the system being simulated into subsystems for which models can be built and tested independently. Thus, constructing a market simulation is a great deal like putting together a picture puzzle in which the individual subsystems, each involving a smaller number of variables, are joined into related parts and tested as subsystems. The proof of whether or not appropriate connections have been made comes in the testing of the completed design for logical alignment among its elements. Admittedly, this long-term view sometimes is thwarted by personnel turnover, making it necessary for newcomers to become familiar with work done previously. Similarly, consulting firms are frequently transient, making it difficult for a company to maintain continuity of effort.

Machine Time and Costs: Efficiency and Costs

When deciding between heuristic and algorithmic approaches, important considerations of time and costs are involved. Conceptually, integer programming could solve most of the complex business problems that have been solved by heuristic methods if there were a machine available to handle the massive calculations required by that algorithm.

But costs become a major factor in cases like these. For example, the small-to-medium-size problem in warehouse location described above has been solved by heuristics in less than one minute on an IBM 704. The same problem solved by integer programming would probably require at least three months of IBM 704 time, provided the core were large enough to store the problem. Since the time required to process integer programming problems increases exponentially as the size of the problem expands, it is clear that only very small and unimportant warehouse problems could be solved by the integer programming methods available today.

The heuristic program that took fifty seconds on the IBM 704 was run in less than ten seconds on the CDC 3600 (the program actually runs so fast on the 3600 computer that an accurate time estimate is difficult—more time is spent getting the program on and off the machine than it takes for the actual running). The original warehouse location program included inputs of fifty customers, twenty-five warehouses, and two products; the problem has since grown to over five hundred customers, more than three hundred warehouses, and twelve products. Arriving at optimal warehouse sites via integer programming could never be carried out today on a time schedule for practical application and would require machine time of such magnitude that the costs would, in all probability, not be justified.

The availability of machine time clearly becomes a crucial factor in the choice among models and methods of solution, and it is fairly evident that the magnitude of problems will grow at least as fast as the capacity of machines to solve them. Sizable savings in computational time and cost are possible with heuristic programming, savings that are further enhanced by larger machines.

To date, after application of the warehouse program with more than a dozen firms, no user has been able to devise an improved solution. One company has succeeded in effecting a cost improvement in machine time of three-fourths of 1 per cent, realized by eliminating one of the constraints in the original set of parameters.

Conclusions: Concreteness and Abstraction

It may seem disrespectful to apply Plato's teaching that business activities are suited only for misfits, in a commercial context. Nevertheless, there is a moral for model builders in his narrative of mankind in the dark cave, a dialogue in which Socrates contrasts the material world of our everyday sense experience with the spiritual world of pure thought and truth.

By observing the shadows of images of outside action projected upon the well of the cave, prisoners in the cave were to construct a model of the real world. A few individuals were allowed to emerge from their confinement to study the phenomena occurring outside, using the new information to add to the basic structure of their original model. Ultimately, the chosen ones saw their own likenesses reflected in a pool, which enabled them to discover their relationship to what had already been observed. Until they left the somewhat abstract world of the cave to see the concreteness of the total arena, "truth (was to them) literally nothing but the shadows of the images" (16). Further, Plato believed that once these appointed thought leaders had attained a thorough understanding of real-life events, they had an obligation to share their knowledge of the world outside by

going back among the captives in the dungeon to participate in their labors of learning.

The responsibility of the business models builder is the same. With so much at stake, it is imperative that he move from the easy generalities of basic mathematical statements to the hard particulars of the complex relationships prevalent in the system he proposes to describe. Perhaps the ideal situation would be for a company to have a qualified, highly experienced practitioner become an expert mathematician so that he could construct the models himself, but this is not likely to happen.

Managers can best facilitate model building by helping builders to learn the system, but they cannot realistically give researchers continuing free rein unless some results are forthcoming. Management is very interested in gambling on such projects, but it needs some confidence that there is a reasonable chance of success.

Occasionally, the researcher's experience is limited, and his judgment is sometimes naïve. Therefore, operating management must effect mutuality between practitioner and researcher and help model builders learn the system, achieving a fruitful synthesis of efforts. As practice not built on sound theory is likely to be useless, likewise theory not tested in practice is relatively meaningless to management. The utility of a model improves through testing—feeding empirical data into it to see how well it works, then making essential modifications, and testing it again.

Almost any model begins crudely and then is refined as it assimilates new information bearing on the problem at hand. But components added over a period of time do not linearly improve the model; rather, accuracy is likely to decrease and become asymptotic. Yet first-stage approximations to reality are inacceptable as long as modifications will enhance the productivity of the model without incurring marginal costs in excess of the marginal return.

Evaluation of the appropriateness of models is far from a simple task. Important questions in determining where the faults lie are: Are parameters set incorrectly? Are minor program subroutines in error? Or is the entire structure of the model unsuitable to the problem? Not infrequently one finds to his dismay that the nature of the output provides few clues to the sources of error, particularly in large-scale simulation models.

The barriers hindering the consumer's purchase of a product—awareness, interest, desire, and action—have their analogue in management's acceptance of mathematical models. Awareness of progressive ways of doing things does not necessarily lead to interest, or if it does, the interest may be casual or even dilettantish. The desire to try such methods, once interest is aroused, may be thwarted by a lack of technical understanding and uneasiness in basing decisions on the findings. If the plateau of action is reached, management may grow discouraged with the rate of progress, become disillusioned, and revert to former habits which seem to be well ordered and easier to comprehend. Once executives reject a technique, the staff specialist will find it tough sledding to sell them on another try.

Even when certain research approaches get the stamp of executive approval, it is quite another matter to persuade planners to utilize the results. There is often a wide gap between analysis and application, which points up a problem touched on but briefly in this article, the problem of a lack of communication and understanding between model builders and model users. There must be provided a suitable climate so that models and machines

can make their maximum contributions to the enterprise.

Managerial decision making may proceed from postulates that are either explicit or implicit, either consistent or inconsistent. Probably no decision framework collectively exhausts all relevant factors that obtain in a situation. Yet adequate structure for use in decision making should permit the inclusion of all available information, because the more closely a logical mathematical system corresponds to the process it represents, the greater its usefulness to management.

Where initial data costs are concerned, it may not be so much a matter of dollar outlays for data as it is the ability to make full use of the information. For example, several companies that once considered panel data too expensive have come to look upon such data as well worth the investment. Of course, any data may be expensive at first, relative to the return in improved understanding, but cumulative gains from interrelated analyses can quickly reverse the imbalance as the models are improved and expanded with additional variables.

Just as one should not be satisfied with naïve models, undue complexity is likewise wasteful in terms of the time necessary to erect the analytical framework, the costs of providing superfluous data to satisfy the needs of the equations, the excessive consumption of machine time, and the ultimate danger that management may accept the output less critically than is called for by the basic nature of the problem. In connection with the last point Alfred North Whitehead said, "There is no more common error than to assume that, because prolonged and accurate mathematical calculations have been made, the application to some fact of nature is absolutely certain."

Caution is advised, especially for behavioral models, in the use of analytic methods such as regression analysis and linear programming. True, readily available analytic methods will speed the analysis but may produce completely unreliable solutions if they are inconsistent with important aspects of the problem. The temptation of fitting problems to available techniques will usually inhibit the careful modeling of the behavioral systems and impede future progress because the foundations are unstable. Yet, as with simple graphical plotting, these convenient algorithms often help to identify functional relationships and can therefore be valuable as preliminary means of exploring various aspects of the system one is attempting to model.

There is a place for traditional optimizing algorithms as well as a place for heuristic problem-solving methods. Such techniques as linear programming, integer programming, quadratic programming, the calculus, and queuing theory are capable of solving a variety of scheduling and resource allocations problems, but there are limitations in the complexity and the size of the problems that can be adequately solved by such optimizing methods. Heuristic programming as a tool for problem solving comes into its own when the assumptions required by rigorous optimizing techniques are either inappropriate to the problem or when, as is frequently the case, the size of the problem prevents the practical application of such techniques.

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Editorial Comment for Chapter 2

Models, in their broadest sense, may be thought of as abstractions from reality that are aimed at imposing a conceptual order in a complex environment. Symbolic models are the recorded product of abstract models formed first in our minds. Symbolic models may take many forms; one form, the mathematical model, is gaining increasing acceptance as an analytic framework for organizational planning and control. If we are interested in decision-oriented information systems, it is important to emphasize that we must also be interested in models and the other tools of contemporary management science as well. Indeed, it seems reasonable to describe an "ideal" information system as a system of descriptive and optimizing models, organized and interrelated to facilitate the accomplishment of organizational objectives.

Morris persuasively argues that there are differences between the teaching of models and the teaching of modeling. These distinctions have important implications for a proper understanding of the skills required of model builders. The implications extend logically to considerations of appropriate content and pedagogy in business schools. If effective planning and control systems require that we simply insert parameter values in standard, ready-made models, then a virtually exclusive emphasis on the teaching of models can be justified on pragmatic grounds. But this is not often the case; the more usual requirement is that models be specifically tailored to fit the system under consideration. The heuristic and simulation models discussed by Hinkle and Kuehn, and Rowe are cases in point. The teaching of models—linear programming techniques, for example—at the expense of the teaching of modeling can foster a climate of models in search of problems rather than problems seeking relevant frameworks for analysis. Clearly, one of the critical tasks facing educators and practitioners alike is to find improved methods of teaching or developing creative modeling skills. The procedure suggested by Morris represents an encouraging step in this direction. To test its usefulness, choose a relatively simple and familiar problem, then develop a model to help you solve the problem. If you successfully obtain a tractable model, you may wish to incorporate additional variables to enrich it. You will find repeated exercises with increasingly more complex situations an invaluable aid in developing modeling skills.

Miller and Starr summarize the sequence of developing a decision model as follows:

1. Choose the objective; specify its dimension and value.
2. Isolate all of the variables that are pertinent to the attainment of the objective value, i.e., the relevant independent variables.
3. Develop the relationships that exist between the independent variables.
4. Distinguish controllable variables (which can be part of the strategy) from noncontrollable variables (classifying the latter as either states of nature or competitive strategies).
5. Develop forecasts and predications for the noncontrollable variables, which should be treated as states of nature. Those variables which have (rational) intelligence behind them must be treated separately by game theoretic methods.
6. Determine whether or not the forecasts and predictions are based on stable processes. This determination can be intuitive, but powerful methods of statistical quality control are available to assist.
7. Develop the function that relates the independent variables to the dependent objective variable.
8. State the restrictions that limit the possible values of controllable variables.
9. Choose those values of the controllable variables (i.e., that strategy) which promise to maximize the degree of attainment of the objective, within the limits set by the restrictions.[1]

Some aspects of dynamic organizational activities do not easily lend themselves to analytical procedures which generate optimal solutions. In such cases, decision makers may turn to computer simulation techniques to gain satisfactory, as contrasted to optimal, solutions. It is interesting to note that Rowe, a simulation enthusiast, underscores the point that the greatest success has been achieved in simulations of physical systems. The literature, on the subject replete with production and inventory control systems applications, tends to support this view. There is, however, ample evidence to suggest that application of the technique to a broader class of problems has begun in earnest. Total-firm and total-systems simulations—as described by Rowe, and Khoury and Nelson (in Chapter 5) and exemplified by industrial dynamics models—point toward this trend. The impact of simulation, as it moves from applications at the operational level of the organization to the strategic planning level, is still an unknown quantity. To state that its probable impact on organizational structure and decision-making styles will be profound may well be a serious understatement.

Discussions with analysts and managers engaged in developing business simulation models almost invariably suggest that a number of indirect benefits result from the activity. One is that those participating in the study gain a broad perspective and acquire new insights into the system under consideration. And policy changes are oftentimes a product of this improved perception. Indeed, a number of companies believe developing business simulation models to be a valuable management training vehicle. Developing such a model may not be the most economical means of evaluating an information system; however, it is likely to expose significant data deficiencies in the system in dramatic fashion.

Heuristic programming, discussed in the Hinkle and Kuehn article, is another

[1] David W. Miller and Martin K. Starr, *The Structure of Human Decisions* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1967), pp. 34–35.

approach to problem solving when analytical optimization models either are not available or cannot be justified on economic grounds. The most promising potential for heuristic programming appears to lie in the unprogrammed decision-making area characterized by ill-structured, nonrepetitive problems. As a method of systematic search for solving ill-structured problems, heuristic programming consists basically of the following steps:

1. Classify problem to be solved and associate with available problem-solving techniques.
2. If available techniques are not appropriate to solving problem, reclassify problem into sub-problems. If each sub-problem can be solved, a solution for the total problem exists.
3. If sub-problems are not susceptible to available solution techniques, reclassify problem into sub-sub-problems.
4. Continue segmenting the problem until either the solution of sub-problems leads to an overall solution or it can be shown that all or certain aspects of the problem cannot be solved.[2]

As Hinkle and Kuehn point out, the choice between a heuristic program and an optimizing algorithm is often difficult, since a comparison of decisions reached via the two approaches may not be made before the modeling effort is undertaken. This ill-structured problem of model choice is likewise an appropriate subject for heuristic programming; here past experience with similar models and managerial judgment are key inputs. Let us postulate that, in any given problem situation, the analyst either has a prior conception of a decision model or gradually develops one. It can be further postulated that this particular decision model either can be simplified or additional complexities can be introduced. The decision-sensitivity approach offers general guidelines for strategic movements in *both* directions along the scale of model complexity. It is, in fact, a sequential testing process operating according to two general rules:

1. Movement up the scale of complexity is warranted when the expected value of the new decision exceeds the expected value of the old decision by a margin greater than the projected incremental costs associated with the increased model complexity.
2. Movement down the scale of complexity is warranted when the projected decremental costs associated with model simplification exceed the difference between the expected value of the old decision and the expected value of the new decision.

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Part II

INFORMATION FOR PLANNING AND CONTROL

3

Basic Framework for Planning and Control

FRAMEWORK FOR ANALYSIS

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This paper presents a framework that is intended to be useful in thinking about the subject of management planning and control systems. It describes in some detail the distinguishing characteristics of the main elements of this framework and points out some of the errors that are made when these distinctions are not recognized. Strategic planning, management control, and technical control are proposed as the basic processes in a useful framework for analysis.

Since dogs and humans are both mammals, some generalizations that apply to one species also apply to the other. It is for this reason that some new surgical techniques can be tested on dogs before being risked on humans. But dogs and humans differ, and, unless these differences are recognized, generalizations that are valid for one species may be erroneously applied to the other. For example, canine behavior can be largely explained in terms of conditioned reflexes, but human behavior is much more complicated. Similarly, some generalizations can be made about the whole planning and control process

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in a business; however, there actually are several quite different types of planning and control processes, and mistakes may be made if a generalization (principle, rule, technique) valid for one type is applied to the other.

The purpose of this article is to suggest a classification of the main topics or "species" that come within the broad term, "planning and control systems," and to suggest distinguishing characteristics of each. Hopefully, this will lead to a sorting out and sharpening of principles and techniques applicable to each species.

The particular classification chosen has been arrived at after careful analysis of how well various alternatives match statements made in the literature and, more important, what is found in practice. It is, however, tentative. Better schemes may well be developed, and we expose this one primarily in the hope that discussion of it will lead to agreement on *some* scheme, not necessarily this.

In this article, we shall focus on a process labeled *management control.* We shall describe its main characteristics, and distinguish it from processes labeled *strategic planning* and *technical control.* (Two other processes, *financial accounting* and *information handling,* are also relevant, but space does not permit a discussion of them here.)

Obviously, we do not assert that these processes can be separated by sharply defined boundaries; one shades into another. Strategic planning sets the guidelines for management control, and management control sets the guidelines for technical control. The complete management function involves an integration of all these processes, and the processes are complementary.

We do assert that the processes are sufficiently distinct so that those who design and use planning and control systems will make expensive errors if they fail to take into account both the common characteristics of a process and the differences between processes. This article will deal with these similarities and differences and point out some of the errors that are made when they are not recognized.

Management Control

Management control is the process of assuring that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives.

Management control is a process carried on within the framework established by strategic planning. Objectives, facilities, organization, and financial factors are more or less accepted as "givens." Decisions about next year's budget, for example, are limited by policies and guidelines prescribed by top management. The management control process is intended to make possible the achievement of planned objectives as effectively and efficiently as possible within these "givens."

The purpose of a management control system is to encourage managers to take actions which are in the best interests of the company. For example, if the system is structured so that a certain course of action increases the reported profits of a division, and at the same time *lessens* the profits of the company as a whole, there is something wrong. Technically, this purpose can be described as *goal congruence.*

"Total" System Necessary

Psychological considerations are dominant in management control. Activities such as communicating, persuading, exhorting, inspiring, and criticizing are an important part of the process.

Ordinarily, a management control system is a *total* system in the sense that it embraces all aspects of the company's operation. It needs to be a total system

because an important management function is to assure that all parts of the operation are in balance with one another, and, in order to examine balance, management needs information about each of the parts.

With rare exceptions, the management control system is built around a *financial* structure; that is, resources and outputs are expressed in monetary units. Money is the only common denominator by means of which the heterogeneous elements of output and resources—e.g., hours of labor, type of labor, quantity and quality of material, amount and kind of products produced —can be combined and compared. (Although the financial structure is usually the central focus, nonmonetary measures such as time, number of persons, and reject and spoilage rates are also important parts of the system.)

The management control process tends to be *rhythmic;* it follows a definite pattern and timetable, month after month and year after year. In budgetary control, which is an important part of the management control process, certain steps are taken in a prescribed sequence and at certain dates each year: the dissemination of guidelines, the preparation of original estimates, the transmission of these estimates up through the several echelons in the organization, the review of these estimates, final approval by top management, dissemination back through the organization, operation, reporting, and the appraisal of performance. The procedure to be followed at each step in this process, the dates when the steps are to be completed, and even the forms that are to be used can be, and often are, set forth in a manual.

Interlocking Subsystems

A management control system is, or should be, a *coordinated, integrated* system; that is, although data collected for one purpose may differ from those collected for another purpose, these data should be reconcilable with one another. In a sense, the management control system is a *single* system, but it is perhaps more accurate to think of it as a set of interlocking subsystems. In many organizations, for example, three types of cost information are needed for management control: (1) costs by responsibility centers, which are used for planning and controlling the activities of responsible supervisors; (2) full program costs, used for pricing and other operating decisions under normal circumstances; and (3) direct program costs, used for pricing and other operating decisions under special circumstances, such as when management wishes to utilize idle capacity. (*Program* is here used for any activity in which the organization engages. In industrial companies, programs consist of products or product lines, and *product costs* can be substituted in the above statements.)

Line managers are the focal points in management control. They are the persons whose judgments are incorporated in the approved plans, and they are the persons who must influence others and whose performance is measured. Staff people collect, summarize, and present information that is useful in the process, and they make calculations which translate management judgments into the format of the system. Such a staff may be large in numbers; indeed, the control department is often the largest department in a company. However, the significant decisions are made by the line manager, not by the staff.

Strategic Planning

Strategic planning is the process of deciding on changes in the objectives of the organization, in the resources that are to be used in attaining these

objectives, and in the policies that are to govern the acquisition and use of these resources.

The word *strategy* is used here in its usual sense of deciding on how to combine and employ resources. Thus, strategic planning is a process having to do with the formulation of long-range, strategic, policy-type plans that change the character or direction of the organization. In an industrial company this includes: planning that affects the objectives of the company; policies of all types (including policies as to management control and other processes); the acquisition and disposition of major facilities, divisions, or subsidiaries; the markets to be served and distribution channels for serving them; the organization structure (as distinguished from individual personnel actions); research and development of new product lines (as distinguished from modifications in existing products and product changes within existing lines); sources of new permanent capital; dividend policy; and so on. Strategic planning decisions affect the physical, financial, and organizational framework within which operations are carried on.

Irregular in Nature

Briefly, here are some ways in which the strategic planning process differs from the management control process.

A strategic plan usually relates to some part of the organization, rather than to the totality; the concept of a master planner who constantly keeps all parts of the organization at some coordinated optimum is a nice concept but an unrealistic one. Life is too complicated for any human, or computer, to do this.

Strategic planning is essentially *irregular*. Problems, opportunities, and "bright ideas" do not arise according to some set timetable, and they have to be dealt with whenever they happen to be perceived. The appropriate analytical techniques depend on the nature of the problem being analyzed, and no overall approach, such as a mathematical model, has been developed that is of much help in analyzing all types of strategic problems. Indeed, an overemphasis on a systematic approach is quite likely to stifle the essential element of creativity. In strategic planning, management works now on one problem, now on another, according to the needs and opportunities of the moment.

The estimates used in strategic planning are intended to show the *expected* results of the plan. They are neutral and impersonal. By contrast, the management control process, and the data used in it, are intended to influence managers to take actions that will lead to *desired* results. Thus, in connection with management control, it is appropriate to discuss how "tight" an operating budget should be: Should the goals be set so high that only an outstanding manager can achieve them, or should they be set so that they are attainable by the average manager? At what level does frustration inhibit a manager's best efforts? Does an attainable budget lead to complacency? And so on. In strategic planning, the question to be asked about the figures is simply: Is this the most reasonable estimate that can be made?

Strategic planning relies heavily on *external information,* that is, on data collected from outside the company, such as market analyses, estimates of costs and other factors involved in building a plant in a new locality, technological developments, and so on. When data from the normal information system are used, they usually must be recast to fit the needs of the problem being analyzed. For example, the current operating costs of a plant that are collected for measuring performance and for making pricing and other op-

erating decisions usually must be restructured before they are useful in deciding whether to close down the plant.

Communications Are Limited

Another characteristic of the relevant information is that much of it is imprecise. The strategic planner estimates what *will* happen, often over a rather long time period. These estimates are likely to have a high degree of uncertainty, and they must be treated accordingly.

In the management control process, the communication of objectives, policies, guidelines, decisions, and results throughout the organization is extremely important. In the strategic planning process, communication is much simpler and involves relatively few persons; indeed, the need for secrecy often requires that steps be taken to inhibit communication. (Wide communication of the *decisions* that result from strategic planning is obviously important, but this is part of the management control process.)

Strategic planning is essentially applied economics, whereas management control is essentially applied social psychology.

Both management control and strategic planning involve top management, but middle management, i.e., operating management, typically have a much more important role in management control than they have in strategic planning. Middle managers usually are not major participants in the strategic planning process and sometimes are not even aware of the fact that a plan is being considered. Many operating executives are by temperament not very good at strategic planning. Also, the pressures of current activities usually do not allow them to devote the necessary time to such work. Currently, there is a tendency in companies to set up separate staffs which gather the facts and make the analyses that provide the background material for strategic decisions.

These and other differences between management control and strategic planning are summarized in Table 1.

Strategic planning and management

TABLE 1

Some Contrasts

	Strategic Planning	*Management Control*
Persons primarily involved	Staff and top management	Line and top management
Number of persons	Small	Large
Mental activity	Creative; analytical	Administrative; persuasive
Variables	Complex; much judgment	Less complex
Time period	Tends to be long	Tends to be short
Periodicity	Irregular; no set schedule	Rhythmic; set timetable
Procedures	Unstructured; each problem different	Prescribed procedure; regularly followed
Focus	Tend to focus on one aspect at a time	All encompassing
Source of Information	Relies more on external and future	Relies more on internal and historical
Product	Intangible; precedent setting	More tangible; action within precedent
Communication problem	Relatively simple	Crucial and difficult
Appraisal of soundness	Extremely difficult	Much less difficult

control activities tend to conflict with one another in some respects. The time that management spends in thinking about the future is taken from time that could otherwise be used in controlling current operations, so in this indirect way strategic planning can hurt current performance. And, of course, the reverse also is true.

More directly, many actions that are taken for long-run, strategic reasons make current profits smaller than they otherwise would be. Research and some advertising expenditures are obvious examples. The problem of striking the right balance between strategic and operating considerations is one of the central problems in the whole management process.

Consequences of Confusion

Following are statements illustrating some of the consequences of failing to make a distinction between strategic planning and management control.

"We should set up a long-range planning procedure and work out a systemized way of considering *all* our plans similar to the way we construct next year's budget." (A long-range plan shows the estimated consequences over the next several years of strategic decisions already taken. It is part of the management control process. Although it provides a useful background for considering strategic proposals, it is not strategic planning. Strategic proposals should be made whenever the opportunity or the need is perceived in a form that best presents the arguments.)

"The only relevant costs are incremental costs; pay no attention to fixed or sunk costs." (This is so in strategic planning, but operating managers are often motivated in the wrong direction if their decisions are based on incremental costs, for example, in intracompany transactions.)

"We may be selling Plant X some day. We should therefore set up the operating reports so that management will have at its fingertips the information it will need when it is deciding this question. For example, we should show inventory and fixed assets at their current market value." (Operating reports should be designed to assist in the management of current operations. Special compilations of data are needed for such major, nonroutine actions as selling a plant. Collection of such data routinely is both too expensive and likely to impede sound operating decisions.)

"Our ultimate goal is an all-purpose control system—integrated data processing—so that management will have all the data it needs for whatever problem it decides to tackle. We should collect data in elemental building blocks that can be combined in various ways to answer all conceivable questions." (This is an impossible goal. Each strategic proposal requires that the data be assembled in the way that best fits the requirements of that proposal. No one can foresee all the possibilities. The "building block" idea is sound within limits, but the limits are not so broad that all problems are encompassed.)

"All levels of management should participate in planning." (All levels of management should participate in the planning part of the management control process, but operating managers typically do not have the time, the inclination, or the analytical bent that is required for formulating strategic plans. Furthermore, such plans often must be kept highly secret.)

Technical Control

Technical control is the process of assuring the efficient acquisition and use of resources, with respect to activities for which the optimum relationship

between outputs and resources can be approximately determined.

The definition of technical control refers to outputs and resources. Outputs are accomplishments of the organization, what it does, and resources are the inputs which the organization consumes. For a whole business, the outputs are the goods and services sold, which are measured by revenues earned, and the inputs are costs and expenses incurred. In rough terms, *outputs* equals *results,* and *resources* equals *costs.*

One of the important tasks in an organization is to seek the *optimum* relationship between outputs and resources. For some activities, this optimum relationship is fairly easy to establish: To manufacture a given part should require such-and-such labor, a certain sequence of machine operations, and so on. For other activities, there exists no "scientific" (even in the loose sense of this term) way of establishing the optimum relationship; for these activities, decisions as to what costs to incur depend on human judgment.

The term "managed costs" is a descriptive one for those types of resources for which an objective decision as to the optimum quantity to be employed cannot be made. An important management function is to make judgments as to the "right" amount of managed costs in a given set of circumstances. These are, by definition, subjective judgments.

Management control applies to the whole of an organization, and to any parts of the whole in which managed costs are significant. Technical control applies to those activities, and only to those activities, in which there are no significant elements of managed cost. Or more simply, in the management control process, management judgment is an important element; in the technical control process, the technique itself is dominant.

As an example of technical control, consider inventory control. If the demand for an item, the cost of storing it, its production cost and production time, and the loss involved in not filling an order are known or can be reasonably estimated, then the optimum inventory level and the optimum production schedule can both be calculated, and reasonable men will agree with the results of these calculations.

In other than exceptional circumstances, these calculations can determine the actions that should be taken. Management intervention is necessary only when these exceptional circumstances arise.

Some Areas Can't Be Measured

By contrast, consider the legal department of a company. No device can measure the quality, or even the quantity, of the legal service that constitutes the output of this department. No formula can show the amount of service that should be rendered nor the optimum amount of costs that should be incurred. Impressions as to the "right" amount of service, as to the "right" amount of cost, and as to whether the relationship between the service actually rendered and the cost actually incurred was "right" are strictly subjective. They are judgments made by management. If persons disagree on these judgments, there is no objective way of resolving the disagreement. Yet the legal department as a part of the whole organization must be controlled; the chief counsel must operate within the framework of policies prescribed by top management. The control exercised in this situation is management control.

Examples of activities that can be subjected to technical control are: automated plants, such as cement plants, oil refineries, and power generating stations; the direct operations of most

manufacturing plants (but often not the overhead expense items); production scheduling; inventory control; the "order-taking" type of selling activity; and order processing, premium billing, payroll accounting, check handling, and similar paperwork activities.

Examples of activities for which management control is necessary are: the total activities of most manufacturing plants, which include such "judgment" inputs as indirect labor, employee benefit and welfare programs, safety activities, training, and supervision; most advertising, sales promotion, pricing, selling (as distinguished from order taking), and similar marketing activities; most aspects of finance; most aspects of research, development, and design; the work of staff units of all types; and management activity itself.

The control appropriate for the whole of any unit which carries on both the technical and the management types of activities is management control. The control of the whole accounting department is management control even though technical control is appropriate for certain aspects of the work, such as posting and check writing.

Some people believe that the distinction between the two classes of activities described above is merely one of degree rather than of kind; they say that all we are doing is distinguishing between situations where control is "easy" and "difficult," respectively. We think the distinction is more fundamental than that and hope this will be apparent from the following brief list of characteristics that distinguish management control from technical control.

Management control covers the whole of an organization. Each technical control procedure is restricted to a subunit, often a narrowly circumscribed activity.

Just as management control occurs within a set of policies derived from strategic planning, so technical control occurs within a set of well-defined procedures and rules that are derived from management control.

Control is more difficult in management control than in technical control because of the absence of a "scientific" standard with which actual performance can be compared. A good technical control system can provide a much higher degree of assurance that actions are proceeding as desired than can a management control system.

Rules Can Be Programmed

A technical control system is a *rational* system; that is, the action to be taken is decided by a set of logical rules. These rules may or may not cover all aspects of a given problem. Situations not covered by the rules are designated as "exceptions" and are resolved by human judgment. Other than these exceptions, the application of the rules is automatic. The rules can in principle be programmed into a computer, and the choice between using a computer and using a human being depends primarily on the relative cost of each method.

In management control, psychological considerations are dominant. The management control system at most assists those who take action; it does not directly or by itself result in action without human intervention. By contrast, the end product of an inventory control system can be an order or a decision to replenish a certain inventory item, and this order may be based entirely on calculations from formulas incorporated in the system. (The formulas were *devised* by human beings, but this is a management control process, not a technical control process.)

In a consideration of technical control, analogies with mechanical, electrical, and hydraulic systems are rea-

sonable and useful, and such terms as feedback, network balancing, optimization, and so on, are relevant. It is perfectly appropriate, for example, to view a technical control system as analogous to a thermostat which turns the furnace on and off according to its perception of changes in temperature. These analogies do not work well as models for management control systems, however, because the success of management systems is highly dependent on their impact on people, and people are not like thermostats or furnaces; one can't light a fire under a human being simply by turning up a thermostat.

A management control system is ordinarily focused on a financial structure, whereas technical control data are often nonmonetary. They may be expressed in terms of man-hours, number of items, pounds of waste, and so on. Since each technical control procedure is designed for a limited area of application, it is feasible to use the basis of measurement that is most appropriate for that area.

Approximations Meet Data Needs

Data in a technical control system are in real time and relate to individual events, whereas data in a management control system are often retrospective and summarize many separate events. Computer specialists who do not make such a distinction dream about a system that will display to the management the current status of every individual activity in the organization. Although this *could* be done, it *should not* be done; management doesn't want such detail. Management does not need to know the time at which lot No. 1007 was transferred from station 27 to station 28; rather, it needs to know only that the process is, or is not, proceeding as planned, and, if not, where the trouble lies.

Similarly, technical control uses exact data, whereas management control needs only approximations. Material is ordered and scheduled in specific quantities, employees are paid the exact amount due them, but data on management control reports need contain only two or three significant digits and are therefore rounded to thousands of dollars, to millions of dollars, or even (in the U.S. Government) to billions of dollars.

A technical control system requires a mathematical model of the operation. Although it may not always be expressed explicitly in mathematical notation, there is a decision rule which states that given certain values for parameters $a, b, \ldots n$, action X is to be taken. Models are not so important in management control. In a sense, a budget and a PERT network are models associated with the management control process, but they are not the essence of the process.

The formal management control *system* is only a part of the management control *process,* actually a relatively unimportant part. The system can help motivate the manager to make decisions that are in the best interests of the organization, and the system can provide information that aids the manager in making these decisions; but many other stimuli are involved in motivating the manager, and good information does not automatically produce good decisions. The success or failure of the management control process depends on the personal characteristics of the manager: his judgment, his knowledge, his ability to influence others.

Technique Is All-Important

In technical control, the system itself is a much more important part of the whole process. Except in fully automated operations, it is an exaggeration

to say that the system *is* the process, but it is not much of an exaggeration. The technical control system ordinarily states what action should be taken; it makes the decisions. As with any operation, management vigilance is required to detect an unforeseen "foul-up" in the operation, or a change in the conditions on which the technique is predicated. And management will be seeking ways to improve the technique. In general, however, the degree of management involvement in technical control is small, whereas in management control it is large.

As new techniques are developed, there is a tendency for more and more activities to become susceptible to technical control. In the factory, the production schedule that was formerly set according to the foreman's intuition is now derived by linear programming. And, although not too long ago it was believed that technical control was appropriate only for factory operations, we now see models and formulas being used for certain marketing decisions, such as planning salesmen's calls and planning direct mail advertising. This shift probably will continue; it is a large part of what people have in mind when they say, "management is becoming increasingly scientific."

Following are statements illustrating the consequences of failing to make a distinction between management control and technical control:

"Computers will make middle management obsolete." (Although computers can replace human beings in technical control, they are not a substitute for the human judgment that is an essential part of the management control process.)

"Business should develop a management control system like the SAGE and SAC control systems that work so well for the military." (The military systems mentioned are technical control systems. They are not related to the management control problem in the military, let alone that in business.)

"The way to improve the management control process is to develop better management decision rules." (This implies that mathematics, rather than human beings, is the essence of management control.)

"Transfer prices should be calculated centrally." (This gives no recognition to negotiation and the exercise of judgment by divisional managers.)

"If you follow the planning and control techniques described in this book, your profits are a near predictable certainty." (This implies that the technique, rather than the quality of management, is the principle determinant of success.)

Summary

We have described several subsystems that come under the general heading, "planning and control systems." Although related to one another, they have different purposes and different characteristics; different ways of thinking about each of them are therefore required. Generalizations about the whole area are, if valid, so vague as not to be useful. By contrast, useful generalizations, principles, and techniques can be developed for each of the subsystems. Mistakes are made when those valid for one subsystem are applied to another.

LONG-RANGE PLANNING: CHALLENGE TO MANAGEMENT SCIENCE

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This paper attempts to define long-range planning as the organized process of making entrepreneurial decisions. It tries to answer three questions asked by managers and management scientists when they hear the phrase "long-range planning": What long-range planning is and what it is not; why is it needed; and what is needed to do long-range planning. The paper concludes with a brief statement why long-range planning can be considered a major opportunity for, and challenge to, management science.

I

It is easier to define long-range planning by what it is not rather than by what it is. Three things in particular, which it is commonly believed to be, it emphatically is not.

1. First, *it is not "forecasting."* It is not masterminding the future, in other words. Any attempt to do so is foolish; human beings can neither predict nor control the future.

If anyone still suffers from the delusion that the ability to forecast beyond the shortest time span is given to us, let him look at the headlines in yesterday's paper, and then ask himself which of them he could possibly have predicted ten years ago.

a. Could he have forecast that by today the Russians would have drawn even with us in the most advanced branches of physical sciences and of engineering?
b. Could he have forecast that West Germany in complete ruins and chaos then would have become the most conservative country in the world and one of the most productive ones, let alone that it would become very stable politically?
c. Could he have forecast that the Near East would become a central trouble spot, or would he have had to assume that the oil revenues there would take care of all problems?

This is the way the future always behaves. To try to mastermind it is therefore childish; we can only discredit what we are doing by attempting it. We must start out with the conclusion that forecasting is not respectable and not worth-while beyond the shortest of periods. *Long-range planning is necessary precisely because we cannot forecast.*

But there is another and even more compelling reason why forecasting is not long-range planning. Forecasting attempts to find the most probable course of events, or at best, a range of probabilities. But the enterpreneurial problem is the unique event that will change the possibilities, for the enterpreneurial universe is not a physical but a value universe. Indeed the central enterpreneurial contribution, and the one which alone is rewarded with a profit, is to bring about the unique

Reprinted from *Management Science,* V (April, 1959), 238–49. Used by permission of Peter F. Drucker and *Management Science.* This article is based on a paper given before the Fourth International Meeting of the Institute of Management Sciences, held in Detroit, October 17–18, 1957.

event, the *innovation* that changes the probabilities.

Let me give an example—a very elementary one which has nothing to do with innovation but which illustrates the importance of the improbable even for purely adaptive business behavior.

A large coffee distributor has for many years struggled with the problem of the location and capacity of its processing plants throughout the country. It had long been known that coffee prices were as important a factor in this, as location of market, volume, or transportation and delivery strategy. Now if we can forecast anything, it is single commodity prices; and the price forecasts of the company economists have been remarkably accurate. Yet the decisions on plant location and capacity based on these forecasts have again and again proven costly blunders. Extreme pricing events, the probability of which at any one time was exceedingly low, had, even if they lasted only for a week at a time, impact on the economics of the system that were vastly greater than that of the accurately forecast "averages." Forecasting, in other words, obscured economic reality. What was needed (as the Theory of Games could have proven) was to look at the extreme possibilities and to ask: "Which of these can we not afford to disregard?"

The only thing atypical in this example is that it is so simple. Usually things are quite a bit more complex. But despite its (deceptive) simplicity, it shows why forecasting is not an adequate basis even for purely adaptive behavior, let alone for the enterpreneurial decisions of long-range planning.

2. The next thing to be said about what long-range planning is not is: *It does not deal with future decisions.* It deals with the *futurity of present decisions.*

Decisions exist only in the present. The question that faces the long-range planner is not what we should do tomorrow. It is: What do we have to do today to be ready for an uncertain tomorrow? The question is not what will happen in the future. It is: What futurity do we have to factor into our present thinking and doing, what time spans do we have to consider, and how do we converge them to a simultaneous decision in the present?

Decision-making is essentially a time machine which synchronizes into one present a great number of divergent time spans. This is, I think, something which we are only learning now. Our approach today still tends toward the making of plans for something we will decide to do in the future. This may be a very entertaining exercise, but it is a futile one.

Again, long-range planning is necessary because we can make decisions only *in* the present; the rest are pious intentions. And yet we cannot make decisions *for* the present alone; the most expedient, most opportunist decision—let alone the decision not to decide—may commit us on a long-range basis, if not permanently and irrevocably.

3. Finally, the most common misconception of all, *long-range planning is not an attempt to eliminate risk.* It is not even an attempt to minimize risk. Indeed any such attempt can only lead to irrational and unlimited risk and to certain disaster.

The central fact about economic activity is that, by definition, it commits present resources to future and, therefore, highly uncertain expectations. To take risk is therefore the essence of economic activity. Indeed, one of the most rigorous theorems of economics (Boehm-Bawark's law) proves that existing means of production will yield greater economic performance only through greater uncertainty, that is, through greater risk.

But while it is futile to try to eliminate risk, and questionable to try to minimize it, it is essential that the risks

taken be the *right risks*. The end result of successful long-range planning must be a capacity to take a great risk, for this is the only way to improve *entrepreneurial* performance. To do this, however, we must know and understand the risks we take. We must be able to rationally choose among risk-taking courses of action rather than plunge into uncertainty on the basis of hunch, hearsay, or experience (no matter how meticulously quantified).

Now I think we can attempt to define what long-range planning is. It is the continuous process of making *present entrepreneurial (risk-taking) decisions* systematically and with the best possible knowledge of their futurity, organizing systematically *the efforts* needed to carry out these decisions, and measuring the results of these decisions against the expectations through *organized, systematic feedback.*

II

"This is all very well," many experienced businessmen might say (and do say). "But why make a production out of it? Isn't this what the entrepreneur has been doing all along, and doing quite successfully? Why then should it need all this elaborate mumbo-jumbo? Why should it be an organized, perhaps even a separate activity? Why, in other words, should we even talk about 'long-range planning,' let alone do it?"

It is perfectly true that there is nothing very new to entrepreneurial decisions. They have been made as long as we have had entrepreneurs. There is nothing new in here regarding the essentials of economic activity. It has always been the commitment of present resources to future expectations, and for the last three hundred years this has been done in contemplation of change. (This was not true earlier. Earlier economic activity was based on the assumption that there would be no change, which assumption was institutionally guarded and defended. Altogether up to the seventeenth century it was the purpose of all human institutions to prevent change. The business enterprise is a significant and rather amazing novelty in that it is the first human institution having the purpose of bringing about change.)

But there are several things which are new; and they have created the need for the organized, systematic, and above all, specific process that we call "long-range planning."[1]

1. The time span of entrepreneurial and managerial decisions has been lengthening so fast and so much as to make necessary systematic exploration of the uncertainty and risk of decisions.

In 1888, or thereabouts, an old and perhaps apocryphal story goes, the great Thomas Edison, already a world figure, went to one of the big banks in New York for a loan on something he was working on. He had plenty of collateral and he was a great man; so the vice-presidents all bowed and said, "Certainly, Mr. Edison, how much do you need?" But one of them, out of idle curiosity asked, "Tell me, Mr. Edison, how long will it be before you have this new product?" Edison looked him in the eye and said, "Son, judging from past experience, it will be about eighteen months before I even know whether I'll have a product or not." Whereupon the vice-presidents collapsed in a body, and, despite the collateral, turned down the loan application. The man was obviously mad; eighteen months of uncertainty was surely not a risk a sane businessman would take!

[1] "Long-range planning" is not a term I like or would have picked myself. It is a misnomer—as are so many of our terms in economics and management, such as "capitalism," "automation," "operations research," "industrial engineering," or "depreciation." But it is too late to do anything about the term; it has become common usage.

Today practically every manager takes ten or twenty year risks without wincing. He takes them in product development, in research, in market development, in the development of a sales organization, and in almost anything. This lengthening of the time span of commitment is one of the most significant features of our age. It underlies our economic advances. But while quantitative in itself, it has changed the qualitative character of entrepreneurial decisions. It has, so to speak, converted time from being a dimension in which business decisions are being made into an essential element of the decisions themselves.

2. Another new feature is the speed and risk of innovation. To define what we mean by this term would go far beyond the scope of this paper.[2]

But we do not need to know more than that industrial research expenditures (that is, business expenditures aimed at innovating primarily peacetime products and processes) have increased in this country from less than $100 million in 1928 to $7 or $8 billion in 1958. Clearly, a technologically slow moving, if not essentially stable, economy has become one of violent technological flux, rapid obsolescence, and great uncertainty.

3. Then there is the growing complexity both of the business enterprise internally, and of the economy and society in which it exists. There is the growing specialization of work which creates increasing need for common vision, common understanding, and common language, without which top management decisions, however right, will never become effective action.

4. Finally—a subtle, but perhaps the most important point—the typical businessman's concept of the basis of entrepreneurial decision is, after all, a misconception.

Most businessmen still believe that these decisions are made by "top management." Indeed, practically all textbooks lay down the dictum that "basic policy decisions" are the "prerogative of top management." At most, top management "delegates" certain decisions.

But this reflects yesterday's rather than today's reality, let alone that of tomorrow. It is perfectly true that top management must have the final say, the final responsibility. But the business enterprise of today is no longer an organization in which there are a handful of "bosses" at the top who make all the decisions while the "workers" carry out orders. It is primarily an organizations[3] of professionals of highly specialized knowledge exercising autonomous, responsible judgment. And every one of them—whether manager or individual expert contributor—constantly makes truly entrepreneurial decisions, that is, decisions which affect the economic characteristics and risks of the entire enterprise. He makes them not by "delegation from above" but inevitably in the performance of his own job and work.

For this organization to be functioning, two things are needed: knowledge by the entire organization of what the direction, the goals, the expectations are; and knowledge by top management of what the decisions, commitments, and efforts of the people in the organization are. The needed focus—one might call it a *model of the relevants in internal and external environment*—only a "long-range plan" can provide.

One way to summarize what is new and different in the process of entrepreneurial decision-making is in terms

[2] For a discussion see Peter F. Drucker, *The Landmarks of Tomorrow* (New York: Harper & Row, Publishers, 1958).

[3] For a discussion of this "new organization," see again my *"The Landmarks of Tomorrow"* mentioned above.

of information. The amount, diversity, and ambiguity of the information that is beating in on the decision-maker have all been increasing so much that the built-in experience reaction that a good manager has cannot handle it. He breaks down, and his breakdown will take either of the two forms known to any experimental psychologist. One is withdrawal from reality; i.e., "I know what I know and I only go by it; the rest is quite irrelevant, and I won't even look at it." Or there is a feeling that the universe has become completely irrational, so that one decision is as good as the other, resulting in paralysis. We see both in executives who have to make decisions today. Neither is likely to result in rational or in successful decisions.

There is something else managers and management scientists might learn from the psychologists. Organization of information is often more important to the ability to perceive and act than analysis and understanding of the information. I recall one experience with the organization of research planning in a pharmaceutical company. The attempt to analyze the research decisions—even to define alternatives of decisions—was a dismal failure. In the attempt, however, the decisions were classified to the point where the research people could know what kind of a decision was possible at what stage. They still did not know what factors should or should not be considered in a given decision, nor what its risks were. They could not explain why they made this decision rather than another one, nor spell out what they expected. But the mere organization of this information enabled them again to apply their experience and to "play hunches"—with measurable and very significant improvement in the performance of the entire research group.

Long-range planning is more than organization and analysis of information; it is a decision-making process. But even the information job cannot be done except as part of an organized planning effort; otherwise, there is no way of determining which information is relevant.

III

What then are the requirements of long-range planning? We cannot satisfy all of them as yet with any degree of competenec, but we can specify them.

Indeed, we can—and should—give two sets of specifications: one in terms of the characteristics of the process itself, another in terms of its major and specific new knowledge content.

1. Risk-taking entrepreneurial decisions, no matter whether made rationally or by tea-leaf reading, always embody the same eight elements:

a. *Objectives.* This is, admittedly, an elusive term, perhaps even a metaphysical one. It may be as difficult for management science to define "objectives" as it is for biology to define "life." Yet, we will be as unable to do without "objectives" as the biologists are unable to do without "life." Any entrepreneurial decision, let alone the integrated decision system we call a "long-range plan," has objectives, consciously or not.

b. *Assumptions.* These are what are believed by the people who make and carry out decisions to be "real" in the internal and external universe of the business.

c. *Expectations.* These are the future events or results considered likely or attainable.

These three elements can be said to *define the decision.*

d. *Alternative courses of action.* There never is—indeed, in a true uncertainty situation there never can be—"one right decision." There cannot even be "one best decision." There are al-

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ways "wrong decisions," that is, decisions inadequate to the objectives, incompatible with the assumptions, or grossly improbable in the light of the expectations. But once these have been eliminated, there will still be alternatives left—each a different configuration of objectives, assumptions, and expectations; each with its own risks and its own ratio between risks and rewards; each with its own impact, its specific efforts, and its own results. Every decision is thus a value judgment. It is not the "facts that decide"; people have to choose between imperfect alternatives on the basis of uncertain knowledge and fragmentary understanding.

Two alternatives deserve special mention, if only because they have to be considered in almost every case. One is the alternative of no action (which is, of course, what postponing a decision often amounts to); the other is the very important choice between adaptive and innovating action—each having risks that differ greatly in character though not necessarily in magnitude.

e. The next element in the decision-making process is the *decision itself.*

f. But there is no such thing as one isolated decision; every decision is, of necessity, part of a *decision structure.*

Every financial man knows, for instance, that the original capital appropriation on a new investment implies a commitment to future and usually larger capital appropriations, which, however, are almost never as much as mentioned in the proposal submitted. Few of them seem to realize, however, that this implies not only a positive commitment but also, by mortgaging future capital resources, a limited future freedom of action. The structuring impact of a decision is even greater in respect to allocations of scarce manpower, such as research people.

g. A decision is only pious intention unless it leads to action. Every decision, therefore, has an *impact stage.*

This impact always follows Newton's second law, so to speak; it consists of action and reaction. It requires effort. But it also dislocates. There is, therefore, always the question: what effort is required, by whom, and where? What must people know, what must they do, and what must they achieve? But there is also the question—generally neglected—what does this decision do to other areas? Where does it shift the burden, the weaknesses, and the stress points; and what impact does it have on the outside—in the market, in the supply structure, in the community, and so on?

h. And, finally, there are *results.*

Each of these elements of the process deserves an entire book by itself. But I think I have said enough to show that both the process itself and each element in it are *rational,* no matter how irrational and arbitrary they may appear. Both the process and all its elements can therefore be defined, can be studied, and can be analyzed. And both can be improved through systematic and organized work. In particular, as in all rational processes, the entire process is improved and strengthened as we define, clarify, and analyze each of its constituent elements.

2. We can also, as said above, describe long-range planning in terms of its specific new knowledge content.

Among the areas where such new knowledge is particularly cogent might be mentioned:

a. *The time dimensions of planning.* To say "long-range" or "short-range" planning implies that a given time span defines the planning, and this is actually how businesses look at it when they speak of a "five-year plan" or a "ten-year plan." But the essence of planning is to make present decisions with knowledge of their futurity. It is the futurity

that determines the time span, and not vice versa.

Strictly speaking, "short range" and "long range" do not describe time spans but stages in every decision. "Short-range" is the stage before the decision has become fully effective, the stage during which it is only "costs" and not yet "results." The "short range" of a decision to build a steel mill is the five years or so until the mill is in production. And the "long-range" of any decision is the period of expected performance needed to make the decision a successful one—the twenty or more years above break-even point operations in the case of the steel mill, for instance.

There are limitations on futurity. In business decisions the most precise mathematical statement is often that of my eigth-grade teacher that parallels are two lines which do not meet this side of the schoolyard. Certainly, in the expectations and anticipations of a business, the old rule of statistics usually applies that anything beyond twenty years equals infinity; and, since expectations more than twenty years hence have normally a present value of zero, they should receive normally only a minimal allocation of present efforts and resources.

Yet it is also true that, if future results require a long gestation period, they will be obtained only if initiated early enough. Hence, long-range planning requires knowledge of futurity: What do we have to do today if we want to be some place in the future? What will not get done at all if we do not commit resources to it today?

If we know that it takes ninety-nine years to grow Douglas firs in the Northwest to pulping size, planting seedlings today is the only way we can provide for pulp supply in ninety-nine years. Some one may well develop some speeding-up hormone, but we cannot bank on it if we are in the paper industry. It is quite conceivable, may indeed be highly probable, that we will use trees primarily as a source of chemicals long before these trees grow to maturity. We may even get the bulk of paper supply thirty years hence from less precious, less highly structured sources of cellulose than trees, which are the most advanced chemical factories in the plant kingdom. This simply means, however, that our forests may put us into the chemical industry sometime within the next thirty years, and we had better learn now something about chemistry. If our paper plants depend on Douglas fir, our planning cannot confine itself to twenty years but must consider ninety-nine years. For we must be able to say whether we have to plant trees today or whether we can postpone this expensive job.

But on other decisions even five years would be absurdly long. If our business is buying up distress merchandise and selling it at auction, then next week's clearance sale is "long-range future," and anything beyond is largely irrelevant to us.

It is the nature of the business and the nature of the decision which determine the time spans of planning.

Yet the time spans are not static or "given." The time decision itself is the first, and a highly important, risk-taking decision in the planning process. It largely determines the allocation of resources and efforts. It largely determines the risks taken (and one cannot repeat too often that to postpone a decision is in itself a risk-taking and often irrevocable decision). Indeed, the time decision largely determines the character and nature of the business.

b. *Decision structure and configuration.* The problem of the time dimension is closely tied in with that of decision structure.

Underlying the whole concept of long-range planning are two simple insights.

We need an integrated decision structure for the business as a whole. There are really no isolated decisions on a product

or on markets or on people. Each major risk-taking decision has impact throughout the whole, and no decision is isolated in time. Every decision is a move in a chess game, except that the rules of enterprise are by no means as clearly defined. There is no finite "board," and the pieces are neither as neatly distinguished nor as few in number. Every move opens some future opportunities for decision and forecloses others. Every move, therefore, commits positively and negatively.

Let me illustrate these insights with a single example, that of a major steel company today.

I posit that it is reasonably clear to any student of technology (not of steel technology but of technology in general) that steelmaking is on the threshold of major technological change. *What they are* perhaps the steelmaker knows, but *that they are* I think any study of the pattern, rhythm, and I would say, morphology of technological development might indicate. A logical—rather than metallurgical—analysis of the process would even indicate *where* the changes are likely to occur. At the same time, the steel company faces the need of building new capacity if it wants to keep its share of the market, assuming that steel consumption will continue to increase. A decision to build a plant today, when there is nothing but the old technology available, means, in effect, that for fifteen to twenty years the company cannot go into the new technology except at prohibitive cost. It is very unlikely, looking at the technological pattern, that these changes will be satisfied by minor modifications in existing facilities; they are likely to require new facilities to a large extent. By building today, the company closes certain opportunities to itself, or at least it very greatly raises the future entrance price. At the same time, by making the decision to postpone building, it may foreclose other opportunities, such as market position, perhaps irrevocably. Management therefore has to understand—without perhaps too much detail—the location of this decision in the continuing process of entrepreneurial decision.

At the same time, entrepreneurial decisions must be fundamentally expedient decisions. It is not only impossible to know all the contingent effects of a decision, even for the shortest time period ahead; the very attempt to know them would lead to complete paralysis.

But the determination of what should be considered and what should be ignored is in itself a difficult and consequential decision. We need knowledge to make it: I might say that we need a theory of entrepreneurial inference.

c. *The characteristics of risks.* It is not only magnitude of risk that we need to be able to appraise in entrepreneurial decisions. It is above all the character of the risk. Is it, for instance, the kind of risk we can afford to take, or the kind of risk we cannot afford to take? Or is it that rare but singularly important risk, the risk we cannot afford not to take—sometimes regardless of the odds?

The best General Electric scientists, we are told, advised their management in 1945 that it would be at least forty years before nuclear energy could be used to produce electric power commercially. Yet General Electric—rightly—decided that it had to get into the atomic energy field. It could not afford not to take the risk as long as there was the remotest possibility that atomic energy would, after all, become a feasible source of electric power.

We know from experience that the risk we cannot afford not to take is like a "high-low" poker game. A middle hand will inevitably lose out. But we do not know why this is so. And the other, and much more common, kinds of risk we do not really understand at all.

d. *Finally, there is the area of measurements.* I do not have to explain to readers of *Management Science* why measurements are needed in management, and especially for the organized

entrepreneurial decisions we call "long-range planning."

But it should be said that in human institutions, such as a business enterprise, measurements, strictly speaking, do not and cannot exist. It is the definition of a measurement that it be impersonal and objective, that is, extraneous to the event measured. A child's growth is not dependent on the yardstick or influenced by being recorded. But any measurement in a business enterprise determines action—both on the part of the measurer and the measured—and thereby directs, limits, and causes behavior and performance of the enterprise. Measurement in the enterprise is always motivation, that is, moral force, as much as it is *ratio cognoscendi.*

In addition, in long-range planning we do not deal with observable events. We deal with future events, that is, with expectations. And expectations, being incapable of being observed, are never "facts" and cannot be measured.

Measurements, in long-range planning, thus present very real problems, especially conceptual ones. Yet precisely because what we measure and how we measure determines what will be considered relevant, and determines thereby not just what we see, but what we—and others—do, measurements are all-important in the planning process. Above all, unless we build expectations into the planning decision in such a way that we can very early realize whether they are actually fulfilled or not—including a fair understanding of what are significant deviations both in time and in scale—we cannot plan, and we have no feedback, no way of self-control in management.

We obviously also need for long-range planning, *managerial* knowledge —the knowledge with respect to the operations of a business. We need such knowledge as that of the resources available—especially the human resources, their capacities and their limitations. We need to know how to "translate" from business needs, business results, and business decisions into functional capacity and specialized effort. There is, after all, no functional decision; there is not even functional data; just as there is no functional profit, no functional loss, no functional investment, no functional risk, no functional customer, no functional product, and no functional image of a company. There are only a unified company product, risk, investment, and so on, hence, only company performance and company results. Yet, at the same time, the work obviously has to be done by people, each of whom has to be specialized. Hence, for a decision to be possible, we must be able to integrate divergent individual knowledges and capacities into one organization potential; and for a decision to be effective, we must be able to translate it into a diversity of individual and expert, yet focused, efforts.

There are also big problems of knowledge in the entrepreneurial task that I have not mentioned—the problems of growth and change, for instance, or those of the moral values of a society and their meaning to business. But these are problems that exist for many areas and disciplines other than management.

And in this paper I have confined myself intentionally to knowledge that is specific to the process of long-range planning. Even so, I have barely mentioned the main areas. But I think I have said enough to substantiate three conclusions:

1. Here are areas of genuine knowledge, not just areas in which we need data. What we need, above all, are basic theory and conceptual thinking.

2. The knowledge we need is new knowledge. It is not to be found in the traditional disciplines of business, such as accounting or economics. It is also not available, by and large, in the

physical or life sciences. From the existing disciplines we can get a great deal of help, of course, especially in tools and techniques, and we need all we can get. But the knowledge we need is distinct and specific. It pertains not to the physical, the biological, or the psychological universe, though it partakes of them all. It pertains to the specific institution, the enterprise, which is a social institution existing in contemplation of human values. What is "knowledge" in respect to this institution, let alone what is "scientific," must therefore always be determined by reference to the nature, function, and purposes of this specific (and very peculiar) institution.

3. It is not within the decision of the entrepreneur whether he wants to make risk-taking decisions with long futurity; he makes them by definition. All that is within his power is to decide whether he wants to make them responsibly or irresponsibly, with a rational chance of effectiveness and success, or as blind gamble against all odds. And both because the process is essentially a rational process and because the effectiveness of the entrepreneurial decisions depends on the understanding and voluntary efforts of others, the process will be the more responsible and the more likely to be effective, the more it is a rational, organized process based on knowledge.

IV

Long-range planning is risk-taking decision making. As such it is the responsibility of the policy maker, whether we call him entrepreneur or manager. To do the job rationally and systematically does not change this. Long-range planning does not "substitute facts for judgment," does not "substitute science for the manager." It does not even lessen the importance and role of managerial ability, courage, experience, intuition, or even hunch—just as scientific biology and systematic medicine have not lessened the importance of these qualities in the individual physician. On the contrary, the systematic organization of the planning job and the supply of knowledge to it should make more effective individual managerial qualities of personality and vision.

But at the same time, long-range planning offers major opportunity and major challenge to management science and to the management scientists.[4] We need systematic study of the process itself and of every one of its elements. We need systematic work in a number of big areas of new knowledge—at least we need to know enough to organize our ignorance.

At the same time, long-range planning is the crucial area; it deals with the decisions which, in the last analysis, determine the character and the survival of the enterprise.

So far, it must be said, management science has not made much contribution to long-range planning. Sometimes one wonders whether those who call themselves "management scientists" are even aware of the risk-taking character of economic activity and of the resultant entrepreneurial job of long-range planning. Yet, in the long run, management science and management scientists may well, and justly, be judged by their ability to supply the knowledge and thinking needed to make long-range planning possible, simple, and effective.

[4] I would like to say here that I do not believe that the world is divided into "managers" and "management scientists." One man may well be both. Certainly Management Scientists must understand the work and job of the manager, and vice versa. But, conceptually, and as a kind of work, the two are distinct.

A PROGRAM OF RESEARCH IN BUSINESS PLANNING

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The purpose of this paper is to outline a program of research which is needed to improve the state of the art of business planning. We have approached this task by relating planning to management science on one hand, and to certain areas of descriptive knowledge on the other. From these relations we have constructed a comprehensive program for research on planning. Some parts of this program are being actively pursued, some are still in need of attention. It is our hope that this paper will contribute to a two-fold purpose: that it will help give the business planner a sense of unique identity, and that it will provide him with a research program which he can pursue in strengthening this identity.

Introduction

In the light of its current popularity, it is easy to forget that formal planning is a very new management tool. A recent survey (1960) of the chemical processing industry (15), which is one of the most progressive users of modern management methods, showed, on one hand, that upward of 90 per cent of chemical firms currently engage in long-range planning and, on the other hand, that practically none used formal planning so recently as 1948.

During this rapid growth of planning practice, the problems and the challenges faced by business planners have undergone a similarly accelerated change. In the early and middle fifties the challenge was to sell business on the advantages of formal planning. A small group of pioneers—spearheaded by Green, Kami, Steiner, and Drucker—devoted itself to spreading the new religion. Their efforts made a significant contribution toward the current acceptance of planning by business. To be sure, today many firms still have no formal plans (26, 33, 41). Among those which have them, there are various degrees of refinement and sophistication. Nevertheless, it is fair to say that the proselyting days are over, that the near standard speech on the hows and the whys and the wonders of planning has pretty much outlived its usefulness. It is time for planners to turn attention to new challenges.

Interesting challenges are in abundance. Adoption of planning has raised a number of pressing questions which the profession is ill-equipped to answer. How much planning is enough; what are the cost-benefit relationships in planning; what kinds of planning are appropriate to different firms, to different business conditions within firms; how should firms organize for planning; how is planning related to control; what is the role of computers in planning; how should planning practices differ among industries; how should uncertainty be handled? These and a host of other questions need to be answered if planning is to become a clearly understood and fully effective tool of management. The issues, the concepts, and the techniques which underlie these answers will someday form a cohesive body of knowledge which will be called a theory of planning. In the past fifteen years the literature on planning has provided a skeleton outline for this theory. The need

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now is to put flesh on the skeleton. This fleshing out can come only from a considerable amount of new research into the problem of the business firm and of the planning process. Our purpose in this paper is to develop a broad framework and directions for such research.

We shall start with a broad review of human knowledge and then narrow it to areas of knowledge which are particularly relevant to business planning. This process would hopefully describe what every well-educated planner should know. It will also point to areas where there is a gap between the state of the art and the needs of business. A delineation of the most important gaps will constitute a program of research in business planning.

As a result we shall see that the gaps are many and needs for new knowledge are urgent. Thus a major challenge to planners today is to engage in active research so that, having sold the idea of planning to business, the planning profession can keep it sold and keep making it an increasingly effective management tool.

Taxonomy of Science

In attempting to circumscribe knowledge which is distinctive and relevant to the job of a business planner, we must be prepared for the conclusion that there is no such distinctive body. It may be that business planning is coextensive with the field of management science. If this were the case, planning would be defined primarily as a job slot and a business process which has no specialized knowledge contents. In order to become a good planner, a person would need to be a competent management scientist. To do research he would select an area of management science in which he is technically competent, and he would do this without special reference to planning.

As one would suspect, the answer is neither black nor white. In this paper we hope to show that, while planning is not a unique and distinctive body of knowledge, neither is it coextensive with management science. A large part of knowledge relevant to planning will be seen to lie *within* management science. Another part of relevant knowledge lies outside management science in economics, organization theory, and theory of knowledge.

A broad taxonomy of human knowledge is shown in Figure 1. Distinctive areas are described by corresponding classes of real world phenomena which are related and which have similar properties. We shall call such classes *disciplines.*

1. The *conceptual discipline* is one which is concerned with *ideas* of and about the world. Two mainstream sciences which study pure ideas are mathematics and philosophy. Both are highly relevant as inputs to both management science and planning. Mathematics provides internally consistent logic structures and appropriate calculi for transformations within the structures. Philosophy is one of two major sources of value systems which provide management analysts with criteria for choice among alternatives.

As its title implies, the conceptual discipline is the only one in our structure which is concerned exclusively with ideas and their relationship and not with empirical observations.

2. The *social discipline* is built on an empirical foundation. It studies behavior, attitudes, and motivation of human beings. In this and the remaining disciplines, science takes two complementary points of view: (a) the

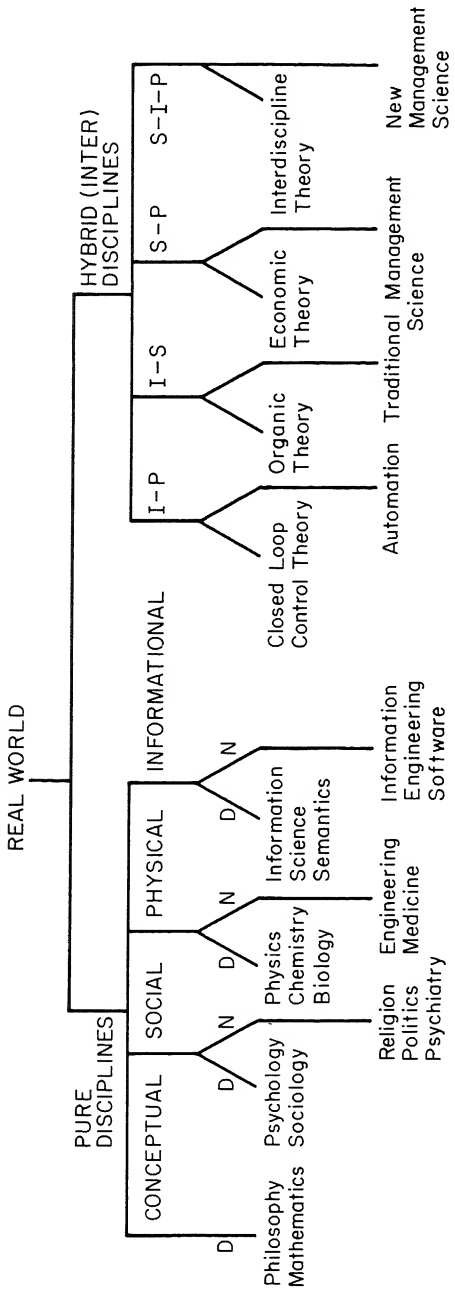


Figure 1

descriptive or predictive viewpoint, which studies the environment "as is" —as it manifests itself to the eyes of the observer; and (b) the *prescriptive* or normative viewpoint, which is concerned with the means by which desired modes of behavior can be induced.

Among major contributions of social sciences to the planning problem are: (a) Empirical data on objectives of organizations and of individuals. This is the second source of value systems; it can be used to confirm or refute the philosophical viewpoint. (b) Knowledge about structure, cohesiveness, and stability of organizations. As will be seen below, this particular contribution will gain in importance as behavior of firms becomes more dynamic.

3. The *physical discipline* includes a long list of natural sciences of which physics, chemistry, and biology are the major historical cornerstones. Their contribution to business planning is through the light they shed on the characteristics, capabilities, and limitations of the resource conversion processes in the firm.

4. The three preceding disciplines represent the historical mainstreams of [the] search for knowledge. During the past twenty years there has been an explosive growth of interest in another homogeneous class of real world phenomena—the *information discipline.* Although at present there is no unanimity on the point, there is a growing body of evidence that information sciences will take their place among the other mainstreams as a study of a distinctive class of real world phenomena.

The potential contribution to business from studies of information is very great. Many of the early ideas and concepts of planning have neglected the problem of information transfer. Accumulated experience suggests the very opposite: that search for infor-

mation, processing of large volumes of data, and communication and acceptance of processed information, all have major influences on the success of business planning.

The above four disciplines may be called the "pure" mainstreams of [the] search for knowledge, each concerned with a distinctive and similar group of phenomena. They may be described as "vertical" searches for knowledge, which formed the core of the scientific tradition prior to the twentieth century. Since the 1900's some of the most promising expansions of knowledge have come from interdisciplinary or "horizontal" searches for knowledge. These are concerned with studies of *systems,* each of which incorporates more than one of the "pure" disciplines. Startling advances in engineering have, for example, been made through closed loop control theory, which is concerned with combinations of physical and informational phenomena. A most promising viewpoint for study of combined social-physical information systems (such as business firms, military organizations) was enunciated in 1948 by Wiener in his now famous theory of cybernetics.[1]

An exploration of the potentials of various interdisciplinary approaches to knowledge is a subject of great currency and interest. It is, however, beyond the scope of this paper. Our interest in such approaches is confined to the fact that a proper purview of management science and, consequently, of planning is properly describable in terms of interdisciplinary systems. One particular interdisciplinary system which made a major contribution to management science is the field of economics, which is concerned with a simultaneous study of social behavior and of conversion and distribution of physical resources in a closed society.

Using the above concepts we can now attempt to describe management science as follows.[2]

1. The bulk of management science to date has been concerned with two-dimensional physical-social interdisciplinary systems. The physical element has provided the substance of the models and the social element, the decision criteria. Much of the work has been focused on conversion and distribution of resources within the firm (e.g., inventory control, production scheduling, distribution). The criteria (measures of effectiveness) have usually been borrowed from classical economics—profit maximization in its various proxy forms.

2. The problem of acquisition, transfer, and handling information has generally been excluded from the models. On the other hand, some "pure" information models have been constructed which exclude both physical resource conversion and economic criteria.

3. Social phenomena of human motivation (other than profit motivation) have generally been excluded from models. As a result, management science has been studying "dehumanized" business firms after the pattern of classical economists.

4. A relatively recent but strong and significant trend has started toward a fully interdisciplinary view of business problems which includes simultaneously physical, informational, economic, and noneconomic behavioral variables.

[1] For a variety of reasons, two of which may be the fact that Wiener's theory was both too far in advance of its time, and not very clearly enunciated, cybernetics did not "take" in the U.S. Experienced observers suggest that it has provided a unifying outlook on study of management in the U.S.S.R.

[2] This definition can be verified by a review of articles which appeared in *Management Science* and similar publication during the past ten years.

5. A very important fact for planners is that *management science has been normative* and that its descriptive insights have been borrowed from the respective "pure" fields of knowledge. On one hand, this implies the assumption that the insights available in pure disciplines are rich enough and adequate for normative models. On the other hand, this also assumes that interdisciplinary combinations of pure knowledge are simply additive and no new descriptive insights result from study of hybrid systems. Experience has shown that neither of these assumptions is correct either for management science or for planning. Thus, for example, the work of Cyert and March (22) shows that it is not a simple matter to combine economic and social behavior. At the present time a principal need in planning is for an interdisciplinary *applied* theory of the firm which is rich enough to resemble real firms and which can provide a better foundation for normative models than the economists' theory of the firm (22, Chap. 2).

In summary, management science can be defined as a normative study of interdisciplinary systems involving human participants. Historically this study has been heavily biased toward the physical resource conversion process in the firm.[3] The recent important and encouraging trend is toward removal of this bias and a balanced view of physical, social, and informational aspects of organizations.

Management science seeks to change and guide organizations toward attainment of some specified purpose (e.g., profit, victory, or personal goals of the participants). Planning also seeks to change and guide organizations through the specific means of strategies, policies, standing rules, plans, and budgets. Therefore, the *normative* aspect of planning is a part of management science. This conclusion is neither novel nor surprising. Two questions are of greater interest: (a) What *parts* of management science are of major interest to planners, and (b) what *descriptive* knowledge should be a part of a planner's equipment? We now turn to the first of these questions.

[3] If an exact parallel is drawn with pure environments (see Figure 1), the word *science* appears inappropriate to a normative body of knowledge. A better term for management science might be "management engineering."

Planning as Part of the Decision Process

In order to place planning within the context of management science, we start with the management process. The process can be described through the Management Decision Cycle shown in Figure 2. We shall break into the cycle at the left of the diagram.

1. Three time consuming management activities are: (a) response to problems which are brought up by others in the organization (*problem triggers*); (b) a continuing search for opportunities which permit improvement of the firm's performance (*search for opportunities*); and (c) periodic review (*clock triggers*) of past performance.

Although by definition management science is concerned with all of the activities shown in Figure 2, it has paid little attention to the problem of search; since in most of its models the opportunities are assumed to be available at the outset of analysis (11, p. 27). Until recently, planners also have contributed little to the problem of search. The growing importance of strategic planning has brought the problem to the forefront. This is clearly an area of important research for planners.

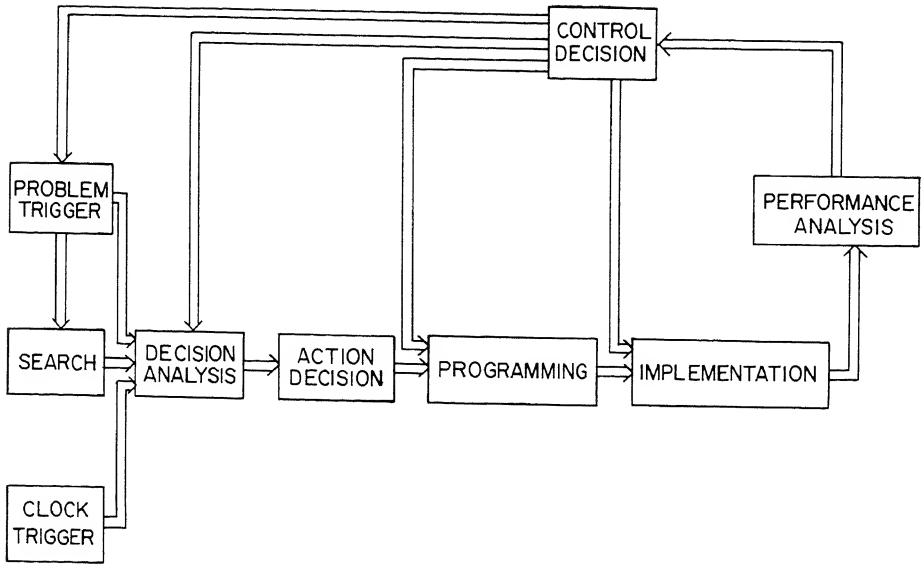


Figure 2

2. The second step—*decision analysis*—has traditionally been a major focus of management science attention. A majority of the published models are concerned with analysis of consequences of *given* alternatives under *given* decision criteria.

Planners, on the other hand, have been remiss in this area. Much of the planning literature has concerned itself with programming of the firm's activities and not with the manner in which the underlying decisions are arrived at. At best, planners are offered checklists: "analyze the problem," "select the preferred course of action," etc. As a result, most planning formats make no provision for explicit recording of decision analysis. It is somehow supposed to be made on "backs of envelopes," or in the manager's head.[4]

In the area of decision analysis, planners need not imitate the bulk of the management science profession and thus become developers of new decision analysis models. They would do better to rely on existing models and focus their attention on the badly needed study of relevance of theoretical models to particular practical situations. In doing this, they can help in several ways: remove a major obstacle to application of good existing models by translating them into business language, point to limitations of unrealistic models, and stimulate development of new, useful models.

A major advance in this area is about to be made through introduction of computers to planning.[5] This will open new vistas for decision analysis and will enable planners to bring the decision maker greatly improved choices of alternatives. If planners are to retain their role as useful advisers to management, they *must* do research and lead in applications of computers in this area.

Another major advance in decision analysis will lie in the emergence of

[4] The military planners have been more progressive in the decision analysis phase through the use of the Estimate of the Situation (23).

[5] For a discussion of computers in planning see (5) and (7).

interdisciplinary descriptive models of the firm in place of the currently predominant economic model. These will broaden the economic-physical resource analysis to include explicit treatment of information and of social interactions among organizational participants. Knowledge in this area is still rudimentary and much research is needed before useful normative models emerge. Planners need to keep current here. They can also make a useful contribution to original research because they frequently have a viewpoint of the firm which is broader and better integrated than that of most management scientists.

3. We have separated the *decision* phase from decision analysis in order to distinguish the problem of building decision models from the problem of formulating decision criteria (utility functions). The aim of the former is to predict consequences of alternatives; the aim of the latter is to determine how a decision maker chooses among the alternatives, given the consequences. In much of the normative problem solving the decision analysis models which structure the relations among variables have generally been better than the accompanying utility functions. This is the reason why, in spite of a large amount of effort devoted to it, utility theory has found very little application in the making of important business decisions. It is fair to say that many otherwise potentially fruitful decision analysis models have not been used in practice because they contained poor decision criteria.

Planners have largely stayed away from study of utility theory primarily because of a frank realization that interest in decision theory can be dangerous to the professional relationship between the planner and the decision maker. Fortunately, in our opinion, little has been lost to planning as a result. Again, as with model building, planners can play a useful role as interpreters by relating various decision theories to practice. They can make an orginal contribution through studying the dimensions of the decision maker's utility spaces and relating these dimensions to the available theories. Thus it is possible to visualize practical use of some utility functions as suboptimization criteria in a larger field of decision variables defined by planners.

4. *Programming* is a management activity which translates decisions into specific action patterns for implementation. The primary management tasks in this phase are:

a. Scheduling activities in support of decisions[6]

b. Assignment and scheduling of resources in support of decisions (commonly referred to as "budgeting")

c. Establishing patterns of work flows in the firm

d. Establishing patterns of authority and responsibility

e. Establishing communication flow networks

This area of management activity has traditionally been the focus of planners. This is where planning was born. Many planners can be found in the profession today who argue that programming, as defined above, is the core and the substance of planning and that the major job of the planner is to serve as: (i) a catalyst in initiating activities a through e above; (ii) as an integrator of the inputs received from the rest of the organization; and (iii) as an interpreter of the results for the management.

[6] The schedules may be time-phased programs, rules for unconditional repetition of activity (standing operating procedures), rules for conditional repetition (policies), or rules for further decision making (strategies). For further discussion of different types of schedules, see (3, Chap. 6).

The scope of planning is, of course, a matter of arbitrary definition. Therefore, we do not propose to argue the right of some planners to define their jobs in this narrow context. It needs to be pointed out, however, that line management is feeling increasing needs for help in the search and decision analysis phases of the decision cycle. The activities in those phases are inextricably related to programming. We would predict, therefore, that planners who refuse to take a broader view of their job are on the way to extinction.

Thanks to the concentration of effort in this area, understanding of programming is better developed than of the other parts of the planner's job. An impressive structure of formats and procedures exists in many business firms which, when properly used, can make a major contribution to the effectiveness of management.[7]

At the same time a number of important research challenges exist in this area:

a. One of these stems from the fact that while most existing business planning systems are effective in *resource scheduling,* they are very poor in *activity scheduling.* This was graphically illustrated in the Polaris missile development when the Navy discovered that, while its contractor had one of the most progressive business planning systems, this system was unable to provide the kind of activity scheduling information which was needed for control of a very large and complex crash project.

Since then, several PERT-type project control systems have been developed and used. However, they have remained tools of management scientists used on a project-by-project basis and largely unintegrated into business planning systems. A major challenge to planners is to develop integrated planning systems which will combine financial and physical resource scheduling with performance scheduling.

b. Another major challenge lies in the need to integrate decision analysis and programming. As discussed above, these two planning phases have remained separate with the former frequently being given a "lick and a promise." As a very undesirable consequence, management was left with little flexibility in making decisions. Key decisions which determined the future of the firm remained imbedded and hidden in programs and budgets. A top manager who did not like the looks of the resulting budgets had no facility for exploring consequences of different decisions (5).

This is another area in which the computer holds great promise. Some firms have already put their budgeting cycle on the computer, with the resulting gain of flexibility in varying assumptions at little cost and loss in time. Research is needed in the following directions: (i) constructing decision analysis models, (ii) developing performance scheduling models and combining them with existing budgeting models, (iii) programming both on the computer, and, finally, (iv) integrating decision analysis and programming into an overall planning model of the firm.

c. A third research challenge lies in the area of organization planning described by item 4d, above. It had been the subject of business attention for at least as long as budgeting. However, it has generally remained dissociated, both substantively and organizationally, from the usual concerns of the business planner: The business planner and the organization planner frequently reported separately to top management, and each performed his job independently of the other.

The research need is to seek an

[7] For a discussion of this structure and its advantages and limitations, see (5).

understanding of *task-oriented dynamic* organization planning which will inject business needs into organizational design. In the past, students of organizations have shown little concern with design to the specifications of the job. Instead, their concern has been largely directed to describing behavior of established organizations and to studying forces which motivate individuals to participate in organizations (8, 34). On the other hand, practitioners of organizational design within firms have somehow managed to remain aloof from the relationship between profitability of the firm and its organizational structure. Furthermore, most of their thinking about organizations has been in static rather than dynamic time-dependent terms.

The need for research in organizational design is highlighted by the new dynamics of the firm's product-market environment (6). If one were forced to state a single central problem which will face the firm of tomorrow, it may well be the need to innovate continuously. And the organizational form is a major instrument for filling the need.

d. A fourth research challenge is posed by item 4e above. It is the need for task-oriented information system design. Unlike organization planning, information system planning is a relatively recent business activity which was brought about by the growing size and complexity of firms and made possible by the capabilities of the computer. The impetus for research in this area was provided by the large scale military warning and control systems such as SAGE. Considerable management science effort has been devoted to the military applications, and, more recently, some leading firms have begun to design and install integrated information systems.

In view of considerable management science interest in this area, our recommendation to planners, unlike in organization design, is that they monitor and adapt work which is current, and which will undoubtedly expand, to the needs of the business firm. It is probable that for some time in the future, business planners and information system planners will continue to work separately on their respective problems. The prospects for eventual integration of their efforts will be discussed below.

5. The fifth stage in management decision cycle, *implementation,* is probably the most time consuming management activity. It consists of

a. Disseminating information about the plans and programs

b. Securing their acceptance by responsible participants

c. Triggering off organizational action

d. Providing coordination among related activities

e. Providing leadership and otherwise motivating the participants

While the general manager's load is heavy in this phase, the planner's attention is confined to a and b. Practical experience and psychological experiments have shown that the best prepared programs may be frustrated and diluted in implementation, unless their content is properly communicated to managers and workers who carry them out and unless the managers and the workers become willing participants in the programs.

Psychological experimentation in this area has centered around the problem of participative versus authoritarian management. The experimenters have sought to measure the extent to which participation by subordinates in decision making improves both the decision-making process and the subsequent implementation. While a considerable amount of research has been done here, the results are far from conclusive (9, 10, 19).

The practitioners of management have sought to resolve the same problem in practice by using participative techniques. This has led to a philosophy of *management by objectives,* which has been adopted by some firms (32). Applied to planning, it involves a programming activity which flows "from the bottom up": from the lowest levels of supervision to top management.

Neither the theoretical nor the practical issues are resolved; much research and experimentation remains to be done. Again our suggestion to planners is to do research on application of theoretical formulation and to suggest useful formulations for further theoretical explorations, rather than to engage in active original research.

6. The remaining two phases of Figure 2, Performance Analysis and Control Decision, have traditionally lain outside the business planner's purview. Frequently the staff responsibility[8] for these functions is lodged with the controller who, in turn, is a member of the finance branch of the firm. Since business planners usually report directly to top operating management, the planning function and the control function are performed in parallel, frequently without a close coupling between them.

While there is much to be said for keeping staff planning and control responsibilities separated, important developments in the art of planning will make it necessary that the planner concern himself with some aspects of measurement and control problems.

a. As discussed above, traditional programming has been adapted to *resource* scheduling which can be measured in terms of dollars. The use of financial measurement as the performance yardstick was the primary reason why the controller's function gravitated to the finance branch.

As *activity* scheduling and measurement is introduced, the logic of having the finance branch perform the control function will become less clear. Regardless of how organizational implications are resolved,[9] planners will have to become concerned with designing activity programs in ways which will enable and expedite effective performance measurement and control. This area of research is very much a job for the planners, since it cannot be effectively separated from the design of activity scheduling systems.

b. The control decision box in Figure 2 shows four possible types of decision which can result from a comparison of performance to plans and programs:

i. To redirect implementation in a way which will result in meeting planned objectives

ii. To seek for alternatives that are different from the one being implemented. This represents a recognition that the fault lies with the decision itself and not the way it was either programmed or implemented

iii. To reprogram the activity without changing the basic objective and nature of the activity

iv. To review the decision analysis procedure. This represents recognition that the process of decision analysis needs improvement: that good alternatives were available but the one chosen was not the best one for the firm.

Of the four control feedbacks planners should have particular interest (and responsibility) for (iii)—reprogram and (iv)—improve decision analysis. These feedbacks are to be fully

[8] The line responsibility in these areas continues, of course, to reside with the responsible line manager.

[9] They may well be resolved in some firms in favor of the data systems manager assuming the control function.

expected, since no procedure can be perfect the first time, and the best way to learn how to plan effectively is to learn from experience.

As a practical matter, feedbacks of this kind do take place. (Sometimes they result in loss of jobs for unfortunate planners.) However, very little research has been done on how to design the planning system so as to assure that feedbacks take place regularly and are used for progressive improvement of planning. This is another research area in which planners should have a firsthand interest.

c. The final research area to be discussed in connection with the management decision cycle is integration of planning and control into combined computer models. As mentioned above, traditionally the planner's job stopped with completion of the programming phase when the controller took over. As the planners become concerned with activity control (see a, above), and as comprehensive planning models are programmed on computers, much of the logic of separation of planning from control will disappear. It will certainly disappear to the point where integrated planning *and* control models of the firm become a reality.

Therefore, planners need to do research on the total planning-control system. The first steps can start at the interface by assuring that plans provide *for* effective control within existing control systems. However, as performance scheduling becomes integrated with resource scheduling, as behavioral elements are introduced into models, a fully integrated planning-control viewpoint should become the object of planning research. In this work the planner will have to work with the controller, each retaining his primary purpose—the former of creating effective guidelines for the firm and the latter in assuring compliance with the guidelines.

Planner as a Specialist within Management Science

By means of the management decision cycle we have described the field of normative knowledge about interdisciplinary purposive systems (such as the business firm) which is of concern to management science. Within this field we have singled out areas of particular concern to business planners. We are now in a position to define both planning and the job of the planner.

We define planning as a process of setting formal guidelines and constraints for the behavior of the firm. This includes search for threats and opportunities, analysis of these, selecting preferred ones, scheduling their implementation, and using performance feedback to improve the process.[10]

Planning is not the exclusive province of the professional planner. On one side, he reports to a line manager, who is an active participant. In particular, the manager has the exclusive prerogative at the "moment of truth," when the decision is made to program and implement a particular action alternative. The planner can and should make recommendations, but he has neither [the] responsibility nor the authority for making the final choice.

On the other side of the planner are

[10] This definition is practically synonymous with a more colorful one by Peter Drucker (24). He defines planning as: "a continuous process of making present entrepreneurial decisions systematically and with best possible knowledge of their futurity, organizing systematically the effort needed to carry out these decisions, and measuring the results of those decisions against expectations through organized systematic feedback."

his colleagues in management science who have a strong interest in the same phases of the management decision cycle. The planner differs from them in several important respects:

1. His interest is directed to models which are of direct relevance and usefulness to the firm. In a compromise between "formalism" and "realism," which each management scientist has to make, the planner inclines toward the latter (22).
2. The planner's job is "on line." As a part of management he is a daily "real time" participant of the ongoing management process. By contrast, many other management scientists within firms operate "off line" (in OR or management science groups) on special problems and assignments.
3. A consequence of the on-line responsibility is the planner's concern with programming, again in contrast to many other management scientists who consider the problem "solved" when the preferred alternative is chosen.
4. Similarly the planner is concerned with organizational acceptance of planning, with implementation, with measurement, and feedback into the planning process.

A Program of Research for Planners

We are now in a position to present a summary program for research in planning. In the beginning of the paper we sought research topics within a broad taxonomy of human knowledge. This provided us with areas of descriptive knowledge which are relevant to the planning process. Secondly, we focused attention on the management decision cycle. This enabled us first to describe in detail the normative field of interdisciplinary knowledge known as management science, and then to single out within it the normative interests of the planner.

Thus both normative and descriptive research topics have been uncovered. We have further made judgment on the manner in which planners should address each topic. The judgments were based on several considerations: special relevance to planning, the importance of a practical viewpoint, urgency of the need for improvements, and the level of current research activity by other management scientists. In the following listing we shall assign each topic to one of three categories: (a) topics on which planners should do original research, (b) topics which offer opportunities for applications of research by others, (c) topics on which planners should be cognizant of research by others. These categories are denoted by three, two, or one asterisks, respectively.

A. Concepts and Methodology

1.* The time is not far distant when every planner will need a general understanding of tools of management science. As a minimum, planners need to be cognizant of computer application, linear programming, decision theory, game theory, and probability and statistics.

2.*** Planners can make original contributions to developing *tests of relevance* for determining the suitability of the theoretical model to practical applications. This would include not only tests of availability of data, variability of data, and sensitivity of model results to data, all of which are fairly well understood, but also tests of alternative mathematical formulations for the accuracy with which they reflect reality.

3.** Research is needed in finding practical application for a large body of existing decision analysis models and models of utility theory.

4.*** Literature is virtually barren in answer to the question: "How can we tell whether the proposed plan is a good plan?"

5.*** Management science has concentrated on models of what has been called "well-structured problems" (39). As planning pervades the firm, planners will be increasingly confronted with *ill-structured problems.* Relatively few management scientists today are motivated by an interest in methodologies of ill-structured problems (2, 3, 4, 25, 36). Planners, by virtue of their on line position and preference for realism, can do useful research on a spectrum of methodologies, ranging from unstructured to fully structured problems.

6.** As mentioned earlier, planners have a strong interest in computer simulations of the business firm (7, 28, 29). Much of early research in this area has been done by people outside planning departments with a resulting lack of realism in some of the models (13).

7.** Planners have a strong interest in development of models which combine realistic decision analysis with detailed implementation scheduling and which are also *dynamic,* in the sense of being able to adjust quickly and efficiently to major changes in decisions.

8.** Planners should have a strong interest in *decision analysis models in which decision alternatives are not known in advance* but are introduced over time (30), and in which *estimates of decision outcomes also change with time.*

9.*** A related need for research deals with *models of search for information and generation of decision alternatives.* (The empirical counterpart of this problem is described below.)

10.*** Turning to the realm of philosophy, research is needed to answer the questions of the role of the firm in society and to the objectives of the firm. Most of the past research in this area has been done by people outside firms. Planners can contribute useful philosophical views from the vantage point of an insider.

B. Social Behavior

The expansion of planning from economic to the broader interdisciplinary viewpoint will depend on a number of important contributions from the social sciences. Planners whose technical training is in this environment can find a number of important areas for research. The following are among them (21).

1.*** Theoretical studies of the firm's objectives must be backed up by empirical studies of goal structure of organizations, as well as by normative models for setting objectives (3, pp. 29–75, 22, 24, 27, 37). A study of the dynamics of objectives formulation and change in relation to the changes of the firm is in particular need of attention.

2.*** Descriptive work by Barnard (8), and Simon and March (34, p. 26) made major contributions to understanding of viability and coherence of organizations. The area of *task oriented* organizational theory is in much poorer shape. Success here will mean extension of research from purely social phenomena to include the economics of physical resource conversion within the firm, as well as the communications system.

3.** An area critical to success of planning is *organizational adaptability to change.* Descriptive understanding is needed of what makes some organizations responsive to change while others fail to respond. A point of departure is probably in the study of social phenomena, but again, the viewpoint will have to be enlarged to a fuller behavioral perspective before useful normative models emerge.[11]

4.** Further work is needed on what determines *organizational acceptance* of plans and the effectiveness of *compliance* with plans. A better under-

[11] For example, some organizations fail to change not because of risk preferences of the participants but because their physical resources are highly specialized.

standing is needed on effectiveness of participative management and particularly of the relative influence of its motivational and cognitive aspects.

C. Physical and Information Resource Conversion

1.* An effective business planner needs to have an understanding of the physical and information resource conversion processes which take place within the firm. Therefore he needs acquaintance with the structure and dynamics of primary resource conversion activities: finance, production, marketing, R and D, as well as of the information generation and use as practiced in accounting and controllership.

D. Applied Theory of the Firm

It is an obvious fact that a researcher who seeks ways to improve the behavior of the firm is in need of a clear understanding of how firms behave. Without this understanding he is akin to a self-made mechanic who seeks to repair an automobile without an understanding of internal combustion principles. It is an unfortunate fact that most planners and many of the management scientists have been such self-made mechanics with respect to the business firm. They have been forced into this role by the lack of an adequate theory of the firm (22, Chap. 2).

Our examination of the taxonomy of knowledge suggests that the foundations of such theory must come from a hybrid combination ("interdiscipline") of the traditional pure disciplines. Research on such a theory is still in its incipient stages and is not widespread (3, 12, 15, 18, 22, p. 28, 30). The need, from the planner's viewpoint, is urgent. Furthermore, a technically competent planner is uniquely qualified to do research on theory which will have a close relation to practice. For these reasons it is our recommendation that the planning profession give high priority to research on the applied theory of the firm.

1. *Comparative descriptions of the firm.* One of the major reasons why much of the economic theory of the firm is inapplicable to the real world stems from a lack of discrimination among individual firms. All firms are expected to follow, in a similar way, the same behavioral hypothesis (maximization of near-term profit). In practice we find significant differences among firms both in their objectives and in the way they pursue the objectives. We need to understand the reasons for these differences.
 a. A series of studies is needed which describes firms' behavior under different sets of circumstances.
 i.*** intraindustry studies of what makes for success and failure patterns
 ii.*** interindustry studies of how different external conditions and different product technologies affect behavior of firms
 iii.*** international studies of behavior patterns in different social-economic environments
 iv.*** intrafirm studies of differences between the internal functions of the firm
 b. i.** A number of speculative papers (1, 31, 38) have appeared which prognosticate *what the computer is doing to the internal management* structure of the firm. These need to be extended and supported with historical data
 ii.*** A companion perception of the influence of *trends external to the firm* on firms' behavior is in much worse shape. Here both theoretical formulations and empirical analyses are badly needed (6)
 c. ** Little has been written about the way *management attitudes* affect the firm's behavior under different conditions, or about how these

attitudes are formed. We suspect that management attitude is one of the major determinants of differences in intraindustry behavior. Success here again requires a hybrid viewpoint of physical, social, and informational phenomena.

2.** *Dynamic theory of the firm.* We believe that the comparative studies of the kind described above will radically change theories of the firm's overall behavior. Most current theories and models are static in the sense that the external product-market environment remains structurally unchanged. Only scalar changes in sales volume, prices, etc. are usually studied. Research is needed on how the accelerated dynamics of the environment affect both descriptive and normative theories of the firm (3, 14).

3.** The third major thrust for research in behavior of firms should be in the direction of combining economic-social and informational variables into interdisciplinary models. The need for this research has been discussed above (12).

4.*** Research is needed on the way firms relate to their environment—specifically, on the manner the environment is searched for threats, opportunities, and other relevant information and the manner in which it is filtered and used by the firm.

5.*** Those who have engaged in research on the business firm are aware of the fact that traditional business data collection, processing, and recording systems frequently lack information needed for constructive research. One of the most pressing and potentially most useful directions for descriptive research is in *designing and installing data gathering systems* which will permit better research on the business firm. The current trend toward automated data systems provides unusual opportunities to do this. Additional data requirements can be introduced at small additional cost—a procedure which was not feasible under manual or semiautomatic data processing.

6.*** Finally, the conceptual work on model verification described above must be matched with practice. Research is needed on planning *experimentation* which can be conducted at justifiable costs within an ongoing business process.

E. Design of the Planning Process

The preceding areas have dealt with a wide range of needs for research on the basic tools of the planner. The last two areas deal with the design of the planning process within the firm. Important as the tool developments are, planner's concern with his own job must take priority. Therefore, if choices are to be made, the remaining areas must be the major focus of research in planning. Many of the relevant topics have been discussed in the section on the management decision cycle. They are briefly summarized below.

1.** Research is needed on adaptation and inclusion of *decision analysis* models into business planning systems.

2.** Available *performance scheduling* and *control* models must be adapted to management use.

3.*** Several stages of model *integration* need research:

i. integration of performance scheduling with resource scheduling
ii. integration of decision analysis with programming into overall planning models
iii. integration of planning and control into overall planning-control model of the firm

4.*** As discussed previously, *application of the computer* to all phaases of the planning process should receive high priority.

5.*** Research is needed on making the planning process *adaptive to the re-*

sulting performance in both the decision analysis and the programming phases.

6.*** The planning process must also be made *adaptive to the internal* and *external dynamics* of the firm.
Special needs are:
 i. planning systems which have a sensitive perception of the changes in the external conditions of the firm
 ii. systems capable of rapid response to drastic changes in the product-market position of the firm
 iii. planning systems which change as the firm changes

7.*** A major effort is needed in designing *planning systems* which can be *tailored to the needs of the firm.*
This include:
 i. development of cost-benefits relations for planning
 ii. design of planning systems to fit the particular threats and opportunities faced by the firm and to its internal structure
 iii. design of planning systems appropriate to different functions within the firm
 iv. tailoring of planning systems to the size of the firm

F. Organizational and Information Design

Organizational planning needs to receive the recognition it deserves as a vital part of the planning process.

1.** Some progress has been made in illuminating the relationship between strategy and organization (14). Broader progress is needed in *task-oriented organizational design.*

2.** Procedures are needed which will *match the organization to the dynamics of the firm's environment.* Particularly needed are organizational forms which will accelerate change within the firm.

3.** Most of organization planning today is static. There is a need for formats, procedures, and models for planning *dynamic time-variant organizations.*

4.*** A specific responsibility of the planner is to organize his own operation. This requires *matching the organization of the planning group to the demands of the firm's planning process.*

5.*** Design of *planning information systems* is in need of research.

6.*** Finally, a better understanding is needed of organizational and planning procedures which enhance *acceptance* of and compliance with plans.

Methodology for Research on Planning

A necessary point of departure for research on planning is a systematic appraisal of the current state of knowledge. Some investigations may build on already well-established conceptual and empirical foundations, while other lines of inquiry may have to begin without any appreciable base of available research findings or relevant theories. Therefore, after an area of research is selected, it is useful to map the internal structural characteristics of existing models. One way to do this is to classify models and other types of information in terms of degrees of relevance to practical uses. This would include assessment of the effectiveness with which models have been abstracted from the real situation, availability of data, computational complexity, and the problem of communicating, and implementing results obtained from the models.

One result of such appraisal might be better definition of the type of research efforts required. For example, comprehensive histories of well-understood planning phenomena may be available in a few cases. The task then is to find applications. In other cases, normative procedures may have been formulated but need testing and refinement through

trial applications. Alternatively, well-specified descriptive hypotheses about organization behavior might be available but as yet untested with empirical data. In a larger number of cases, the state of knowledge will probably require formulation of meaningful hypotheses before other stages of research and development can be initiated.

A key issue in methodology for research on planning is the trade-off between precise, manipulable models versus accurate but prescriptively ambiguous models. The costs and benefits of "formalism" versus "realism" for activities of management scientists have been noted by Minas (35). As stated previously, the business planner, more than the management scientist, should be an "on-line" participant in the management process. Therefore, the planner is particularly sensitive to constraints on resources available for his decision analyses, and the plausibility of his management process inputs to the executives who use them. It follows that research on planning must place priority on realism rather than formalism when this trade-off is encountered.

Although "realism" is more appropriate to research on planning than "formalism," two qualifications must be mentioned. First, if realism is sought only through increasing model size and complexity, problems may occur in validating the model as an accurate reflection of a system or an operation. Conway has cited some of these difficulties in connection with research in computer simulation (20). He further suggests that thorough working knowledge is needed of how individual components in a system operate, and that complex simulations are most useful in preliminary explorations. These suggestions deserve attention in efforts to gain realism through computer simulations in research on planning. Second, formal models may be useful predecessors to realistic models. A precise, highly abstract, normative model may generate hypotheses which can be measured and compared more easily than highly detailed description. Such results, plus explicit statements via the model of factors which are and are not included in the analysis, can be fed back through successive stages of model redesign to converge on relevant working techniques for the planner.

The existing state of knowledge and the difficulties inherent in assuring the relevance of research results have implications for the rate of research progress in planning. They suggest that there may be important differences between what is researchable in the form of extensions from existing information, and what is desirable in the form of solutions to the planning problems of the total business enterprise. The research program proposed here includes numerous possibilities for incremental extensions of existing boundaries of knowledge. Research undertaken in these areas can provide opportunities for development and testing of improved methodologies and thereby can contribute to an accelerated advance toward understanding and solving the significant problems of business planning.

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Editorial Comment for Chapter 3

Readings for this chapter were selected for their conceptual insights into management planning and control systems. As Anthony points out, a failure to develop a viable framework with a clear distinction of the different purposes related to each of the subsystems in the framework can lead to significant errors in information system design.

The Anthony article has since been expanded into his frequently cited book, *Planning and Control Systems: A Framework for Analysis.*[1] In the book Anthony substitutes the term "operational control" for "technical control," which was used in the article. The former term seems somewhat more descriptive and appears to be more commonly used; consequently, the term "operational control" will be used here. It is interesting to note that Anthony's distinction between operational control and management control closely corresponds to Simon's distinction between programmed and nonprogrammed decisions.[2] While Anthony readily concedes that in some cases the distinctions among strategic planning, management control, and operational control may not be too precise, the classification of selected business activities in Table 1 should aid the reader in implementing the suggested framework.[3]

The importance of measurement, particularly in the strategic planning and management control processes, is emphasized by Drucker who states that "any measurement in a business enterprise determines action—both on the part of the measurer and the measured—and thereby directs, limits, and causes behavior and performance of the enterprise. Measurement in the enterprise is always motivation, that is, moral force, as much as it is *ratio cognoscendi.*" We will defer detailed discussions of the behavioral impact of information in organizations until Part III, but not without emphasizing its importance to the planning and control models presented in Part II of this book. For example, in the editorial discussion of decentralized financial control systems in Chapter 8, the suggestion is made that the disparity between discounted cash-flow investment planning models and divisional control based upon accounting or book rate of return measurements can motivate divisional managers in a direction contrary to overall organizational goals.

[1] Robert N. Anthony, *Planning and Control Systems: A Framework for Analysis* (Cambridge, Mass.: Harvard University Press, 1965).

[2] Herbert A. Simon, *The New Science of Management Decision* (New York: The Macmillan Company, 1960).

[3] Anthony, *op. cit.*, p. 19.

TABLE 1

Examples of Activities in a Business Organization Included in Major Framework Headings

Strategic Planning	*Management Control*	*Operational Control*
Choosing company objectives	Formulating budgets	
Planning the organization	Planning staff levels	Controlling hiring
Setting personnel policies	Formulating personnel practices	Implementing policies
Setting financial policies	Working capital planning	Controlling credit extension
Setting marketing policies	Formulating advertising programs	Controlling placement of advertisements
Setting research policies	Deciding on research projects	
Choosing new product lines	Choosing product improvements	
Acquiring a new division	Deciding on plant rearrangement	Scheduling production
Deciding on non-routine capital expenditures	Deciding on routine capital expenditures	
	Formulating decision rules for operational control	Controlling inventory
	Measuring, appraising, and improving management performance	Measuring, appraising, and improving workers' efficiency

In a further discussion of the behavioral aspects of information, Drucker states that "organization of information is often more important to the ability to perceive and act than analysis and understanding of the information." While one would certainly not take issue with the value of organized information, it seems reasonable to state that the value created is, in fact, due to improved analysis and understanding of the information that results. To put it somewhat differently, organization of information should not be judged to be more or less important to decision making than analysis and understanding of information; instead, it should be viewed as a key factor in promoting improved analysis and understanding. This point seems particularly relevant to Drucker's illustration regarding the organization of research planning in a pharmaceutical company.

Like the Anthony and Drucker readings, the Ansoff-Brandenburg reading presents a framework for visualizing the organizational planning process. In addition, the authors outline an interesting and ambitious research program to improve business planning. If we agree that information is a key ingredient in the planning process, then clearly the following questions posed by Ansoff and Brandenburg should be of deep concern to information systems designers:

1. How much planning is enough?

2. What are the cost-benefit relationships in planning?
3. What kinds of planning are appropriate to different firms? To different business conditions within firms?
4. How should firms organize for planning?
5. How is planning related to control?
6. What is the role of computers in planning?
7. How should uncertainty be handled?

Each of these questions can serve as an effective point of departure for research on planning. Let us briefly examine several other potential research topics suggested by Ansoff and Brandenburg. The authors claim an absence of research aimed at answering the question: "How can you tell whether the proposed plan is a good plan." In the American Accounting Association publication *A Statement of Basic Accounting Theory*,[4] four basic standards were recommended for evaluating potential information: relevance, verifiability, freedom from bias, and quantifiability. Can these criteria be effectively employed to distinguish satisfactory from unsatisfactory plans? Is the "goodness" of a plan an attribute to be judged quite apart from the ultimate results of implementing the plan? Drucker submits that long-range planning is necessary because of the uncertainties of forecasts. Does this mean that we cannot assess the quality of the planning process until all outcomes are known? Many other pertinent questions must be asked and answered if we are to establish guidelines for measuring the value of proposed plans. The difficulty of this type of research would undoubtedly be more than offset by the potential for improvements in the state of the art in organizational planning.

Further research on computer simulation and methodologies (e.g., heuristic programming) for solving ill-structured problems is also proposed. Interestingly, Ansoff and Brandenburg believe that much of the past research on organization objectives has been done by observers outside the organizations and that planners can develop useful insights from the vantage point of an insider. Can the professional planner who has neither responsibility nor authority to determine ultimate decisions be effectively involved in objectives formulation? Ideally, the planner should be endowed with a systems viewpoint which not only takes into account existing interrelationships within the firm but also considers the firm's relationships with its environment. The "ideal" planner would presumably have a good working knowledge of such disciplines as economics, mathematics, and the behavioral sciences. The need for interdisciplinary thinking in designing integrated planning systems is apparent in the approach recommended by Johnson, Kast, and Rosenzweig:

1. Appraise the future political, economic, and competitive environment.
2. Visualize the desired role of the company in the environment.
3. Perceive needs and requirements of customers.
4. Determine changes in the needs and requirements of other interested groups—stockholders, employees, suppliers, and others.

[4] *A Statement of Basic Accounting Theory* (Evanston, Ill.: American Accounting Association, 1966).

5. Provide a system of communications and information flow whereby organizational members can participate in planning processes.
6. Develop broad goals, objectives, and plans which will direct the efforts of the total organization.
7. Translat[e] this broad planning into functional efforts on a more detailed basis—research, design and development, production, distribution, and service.
8. Develop more detailed planning and control of resource utilization within each of these functional areas—always related to the overall planning effort.[5]

Relating the above sequence to Anthony's proposed framework, steps 1 through 6 can be considered part of the strategic planning process; step 7 relates to management control and step 8 to operational control. Note that the eight steps are also compatible with the Ansoff-Brandenburg definition of planning "as a process of setting formal guidelines and constraints for the behavior of the firm."

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4

Coping with Uncertainty of Relevant Planning and Control Variables

FORECASTING CONSIDERATIONS IN DESIGN OF MANAGEMENT INFORMATION SYSTEMS

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An effective management information system should be designed to forecast short-term customer demand and then quickly to disseminate this information to interested parties in the organization. Such an arrangement facilitates timely responses to changes in a firm's environment by substantially reducing information and reporting lags. Subject to limitations of cost and availability of data, forecasting should take place at the lowest possible level of detail within the shortest forecasting cycle available. Mathematical forecasting techniques should be complemented by executive judgment.

A close examination of routine business decisions will reveal that many of them involve a forecast of events to come. The uncertainly about the outcome of events is, of course, built into our competitive economic system to assure maximum flexibility and rapid adjustment to consumer needs. Flexibility, however, costs money. It can be bought with a liberal inventory of ample supplies of finished, semifinished goods, and raw materials. Flexibility

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can be bought also by a combination of policies that require excessive plant capacity, fluctuating employment levels, purchasing less than economic order quantities, use of overtime, heavy expense for expediting staffs, or employment of fast but expensive means of transportation.

There is, fortunately, another and better way for a business to cope with the rapidly changing environment. A carefully designed information system will anticipate the consequences of various interactions in its organization and transmit them rapidly to every participant whose decisions affect expected overall costs.

Segmentation of the Information Process

The flow of information in a typical organization with its own raw material, production, and distribution facilities is characterized today by excessive segmentation and emphasis on historical reporting. This is illustrated by Figure 1.[1]

Customer needs are satisfied rapidly

[1] This is an idealized chart, characteristic of relationships in many consumer goods operations. Except as noted, all of the facts mentioned in this article are quoted for illustrative purposes only and do not represent existing operating statistics of any particular organization.

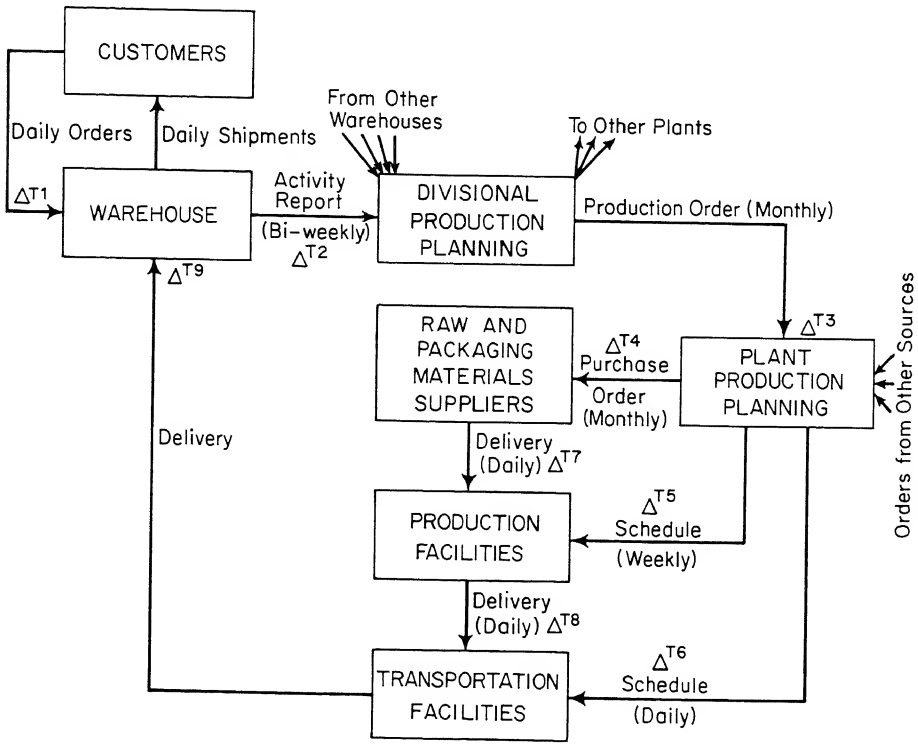


Figure 1

Information flow in a representative production-inventory system

by daily shipments. Information about these needs then goes to the divisional production planning staff who impart to it the latest marketing thinking before passing along their reaction to warehouse conditions and recommendations to the plant production planning staff in the form of a production order. Upon receipt of the order, the plant people consider local conditions, such as plant inventories of goods in process, inventories of supplies, short-term problems in labor efficiency, employment stabilization, and production orders from other sources, before placing an order with raw and packaging materials suppliers for delivery in time to make the desired production run and thereby replenish warehouse inventory.

It is this method of passing information that we call *segmentation*. Commands about corrective actions needed are passed through a chain of specialists, each adding at his station to the original information certain additional elements which are necessary to reflect the marketing, production, and distribution realities of the entire system. This is very like an assembly method of production where the entire process must proceed in a strictly predetermined sequence at a carefully pre-engineered speed.

The facts received at any of the stations along the line are essentially records of past events. Depending on: (1) the nature of the decision rules applied at each station of the information flow, (2) the magnitude of time-lags between each station, and (3) the stability of the pace setting demand pattern at the customer level, one can determine the degree to which reliance on purely historical reporting will call for extreme variations in production rates.[2]

When an organization examines the total cost of producing and distributing its products, it may find that marketing flexibility, which is becoming a necessity in our increasingly competitive environment, may indeed be purchased by market-oriented deployment of inventories, faster means of transportation, or more adaptable production methods. It is becoming more apparent that a thorough reexamination of the expenses associated with segmented communications and with actions based on historical records may uncover significant payoff opportunities for many corporations concerned with the mounting costs of meeting high customer service standards.

The Cost Penalty for Segmentation

The cost penalty for segmentation of the information process is best estimated by analyzing the delays in an existing system. Table 1 shows how such an analysis may be tabulated for the production-inventory system in Figure 1. Possible findings:

Cost of Carrying Inventory

Since the requirements of customer service for consumer goods are exceedingly high (between 96-99 per cent on-time delivery reliability), it can be stated as a first approximation, that for products in mass production, the minimum inventory requirement to support such a service will approach the manufacturer's maximum system reaction time. Hence, all elements which contribute to the maximum delay range and which result from the internal

[2] The work done by Professor J. Forrester at M.I.T. in the field of industrial dynamics provides the framework for conducting such analysis. See J. W. Forrester, "Industrial Dynamics," *Harvard Business Review* (July–August, 1958), for a management introduction; and J. W. Forrester, *Industrial Dynamics* (Cambridge, Mass.: The M.I.T. Press, 1962), for a more, technical description.

TABLE 1

Information Delay Analysis (in Weeks)

Delay Symbol	*Explanation*	*Average Duration*	*Range*
ΔT_1	Orders placed for future delivery and not reflected in warehouse records*	0.6	0.2 – 2.0
ΔT_2	Delay for biweekly reporting	1.0	0 – 2.0
	Sensitivity of four-week moving average†	1.0	0 – 2.0
	Reporting lag—accounting reconciliation and transmission of data	0.5	0.5 – 0.8
ΔT_3	Reporting lag—administrative time and transmission of data	0.2	0 – 0.5
ΔT_4	Production scheduling administrative time	0.4	0.4 – 0.6
	Order placement with vendor	0.2	0 – 0.2
ΔT_5	Manpower assignment time due to union rules‡	1.0‡	1.0 – 1.0‡
ΔT_6	Rail car availability planning‡	0.2‡	0.2 – 0.6‡
ΔT_7	Supplier delivery lead time	1.0	0.2 – 2.0
ΔT_8	Variation in scheduled output	0.2	0 – 0.6
ΔT_9	Transit time	0.8	0.5 – 1.2
		5.9	1.8–11.9

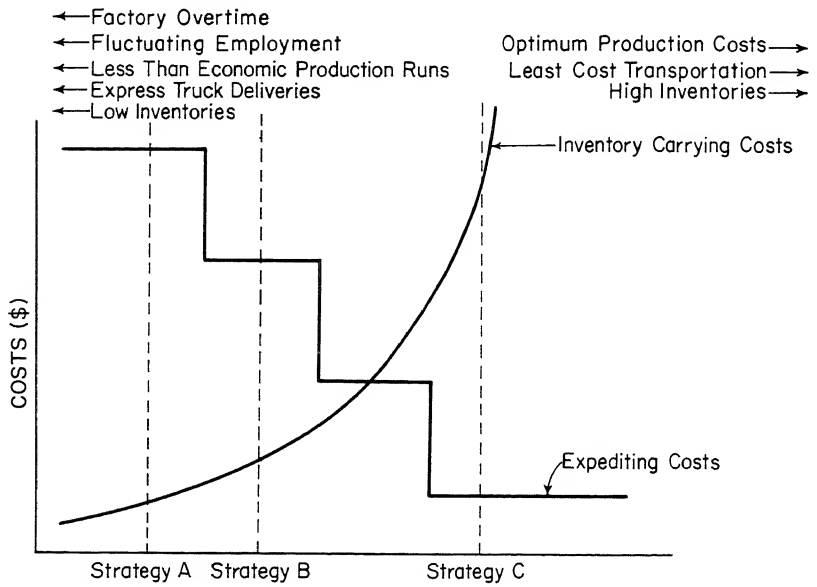
* This delay can be introduced by strict adherence to accounting procedure. Since up to 15 per cent of pending orders may be subject to several days' delay, the rules frequently require only posting of orders with firm delivery dates. This shows how accounting practices may conflict with the need of the organization to get the best information available, even though it may be incomplete.

† To make the re-ordering decision, a four-week moving average of past warehouse shipments is a fairly common practice.

‡ Usually not additive to cumulative delays because path through ΔT_4 and ΔT_7 is the governing delay.

Figure 2

Expediting costs and supply systems policies



administrative process should be immediately earmarked for further investigation. Accordingly, this would classify delays ΔT_1, ΔT_2, ΔT_3 and ΔT_4 as prime candidates for analysis.

Secondary Suppliers' Inventories

Here one must learn whether the delivery lead times (ΔT_7) of the secondary suppliers are supported by inventory levels or surplus capacity. The secondary suppliers must somehow meet the uncertainties of the prime manufacturer's fluctuating production levels. As a rule, if there are suppliers who devote a large share of their total capacity to a single major manufacturer, one must carry the analysis of the consequences of information delays to the secondary level as well, inasmuch as costly practices may be prevailing here to satisfy the manufacturer's rapidly varying need for raw and packaging materials.

Expediting Costs

A clue that these may be substantial can be found in the spread between the minimum and maximum information delay as tabulated in Table 1. A large difference between the average reaction delay and the minimum possible delay will invariably result in a shift to expediting as a method for maintaining customer service.

A combination of cost expediting strategies for obtaining a desired level of customer service is shown in Figure 2. It seems that introduction of inventory controls reinforces the tendency toward Strategy A because expediting penalties are found in a variety of accounts reflecting operating costs, whereas inventory levels are generally singled out as a special item on financial statements. For this reason, claims of an inventory reduction are valid only if there is no offsetting increase in operating costs.

Uses of Forecasting

Delays in a segmented information system can be sharply reduced by reorienting the flow of data. Such an alternative should be considered if it offers:

1. The possibility of a reduction in average and maximum delay in total reaction to customer requirements. (Cost savings attainable through such a reduction can be identified by charts listing the varying delays and associated costs. For the system illustrated in Figure 1, we would draw a set of curves shown as Figure 3.)
2. An information handling capability that does not disrupt the necessary functions of the organization
3. An information system which would be substantially less costly than potential savings identified

It turns out that introduction of forecasting techniques throughout a segmented information system makes it possible to substantially reduce maximum information and reporting lags, simplify organizational and reporting relationships, and reduce overall administrative costs of providing proper information to all decision-makers in the system.

As can be seen from Figure 3, the physical time required for production of the hypothetical consumer item is relatively small as compared with the planning lead time. Under these conditions the ideal system solution is to devise the most accurate techniques practicably attainable to forecast customer sales.

Such forecasts should be translated instantaneously into actionable instructions to decision points within the supply system to gain the closest possible coordination of all stages in the interlinked sequence of events. If perfect accuracy and instantaneous communications could be realized, inventories at the raw, semifinished, and finished levels would reach a minimum, expedit-

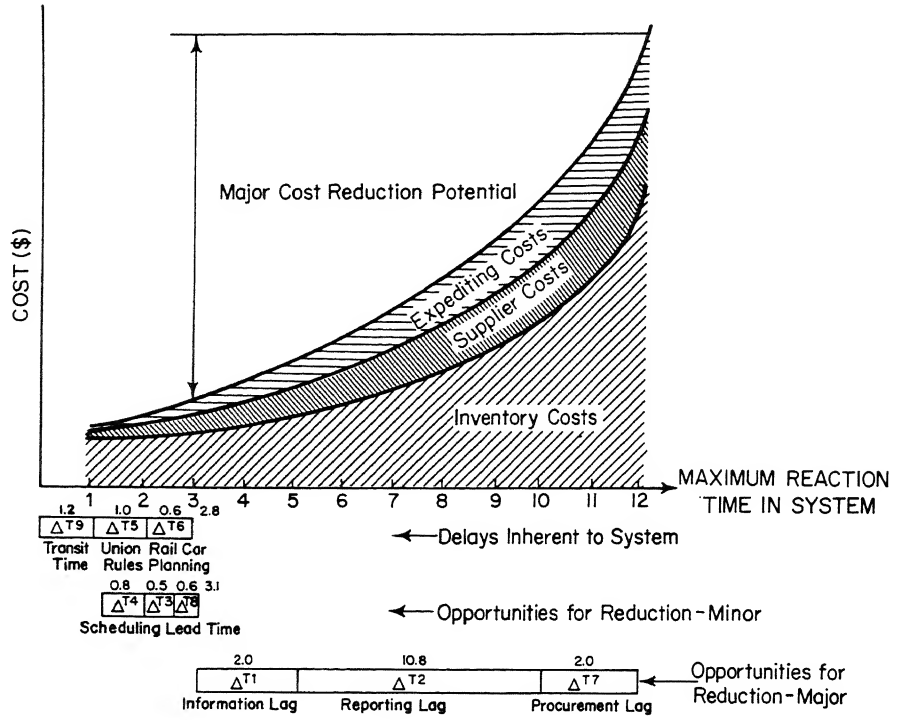


Figure 3

Identifying cost reductions possible from changes in information flows

ing costs would be minor, and purchasing agents would not have to call on suppliers to inquire about delayed deliveries.

Unfortunately, forecasting and communications are subject to very real limitations. The designer of future information systems will have to balance many conflicting elements before he can recommend to his management a method that would realize the maximum savings available.

Attainment of a new optimal design will be important because the properties of such information systems, not unlike the command and control systems that govern the deployment, logistics, and ultimate use of modern weapons, will become an integral part of the overall performance characteristics of a manufacturer's product line. This means that a manufacturer possessing a well-designed technique for identifying the needs of customers will be able to ship, warehouse, market, service, manufacture, and purchase his products at a lesser cost than a competitor whose overall strategy provides little room for information handling based on the best technologies available.

The Costs of Forecasting

Forecasting is expensive. At General Foods, for example, customers demand about 1,000 product items a week at each of approximately twenty-five warehouse locations. To make a correct shipping decision from plants to the warehouses involves a minimum of 25,000 short-term sales forecasts or well over one million forecasts a year. Actually, short-term forecasts are not

always adequate, for certain products customer demand for several weeks ahead must be continually reappraised. Hence, the yearly number of forecasts at General Foods can come to ten million or more.

The question of affordability is obviously important. Several mathematical models for demand forecasting costs are now available. The classical statistical correlation methods[3] are clearly priced out of further consideration for massive applications, since unit costs range from $5 to $25 per forecast. The power of these techniques applies primarily at a high level of aggregation such as in making consumption projections for a broad product line at national or regional levels, which results in tens or hundreds of forecasts per annum. Time series analysis,[4] particularly the type used by statisticians and economists for adjusting historical data about employment, industrial activity, or sales volume, has costs comparable to the various correlation methods and, for this reason, is also not affordable.

It is only when we investigate a simple technique such as moving averages that costs are sufficiently lowered to cents per unit so that mass forecasting becomes practical. Even here, however, there are limitations,[5] hence, the technique of "exponential smoothing" recently has come to the forefront and is in extensive use.[6] Using a large-scale computer, General Foods now produces in excess of ten million customer demand forecasts per annum at a unit cost of less than one cent per forecast. It is interesting to note that both economies of scale and a steep learning curve[7] seem to apply, since our unit costs ran about 4.5¢ per forecast when our current information system became operational on a more limited scale two years ago.

Organization of Forecasting

Who will do forecasting has always been a major organizational question. Should the production manager schedule output levels to satisfy sales forecasts made by the sales manager? What latitude is allowed to the production manager in "second-guessing" the probable outcome of a promotional campaign, particularly if it calls for heavy factory overtime and in the past has resulted in merchandise returned for rework to the plant? Is it mandatory for a plant manager to firm up his production schedule before the purchasing agent orders supplies subject to high obsolescence?

Each question reveals conflicting objectives. Each underscores the fact that the efficient performance of one man depends in large part on the accuracy of the forecast received from another.

The organizational implications of such conflicts and dependencies become even more apparent when we observe elaborate procedures for transmitting forecasts from one level of decision-making to another. Each party in the information chain must protect himself with safeguards against error. But uncertainty is inherent in the business environment. Under rapidly changing conditions even good forecasts become

[3] See *Forecasting by Generalized Regression Methods—Non Linear Estimation,* Program M 2 A-3, IBM Applications Library, New York.

[4] See Julius Shiskin, *Occasional Paper No. 57,* National Bureau of Economic Research, 1957.

[5] See R. G. Brown, *Smoothing, Forecasting and Prediction of Discrete Time Series* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1963), Chap. VII.

[6] For instance, see IBM's manual on IMPACT, a standard program for the management of inventories in distribution industries.

[7] See Winfred B. Hirschmann, "Profit from the Learning Curve," *Harvard Business Review* (January–February, 1964).

obsolete while being communicated.

The complexity of the market itself also tends to promote inaccuracy. A nationally marketed product line is exposed at several thousand stock points to uncertainties of customer demand and to marketing activity initiated by its own or the competitors' sales forces. To describe the *status quo* of such a product line at any given time requires analysis of tens of thousands of facts. Usually this analysis is beyond the capability of staff specialists appointed to coordinate schedules, particularly if their interests are concerned with separate elements of the entire process, such as production, traffic, distribution, and procurement.

These, then, are the forces which underlie the need for reporting segmentation and information transmission delays so costly to an enterprise.

It appears that the most efficient way to organize the forecasting function is to strip it of its narrowly departmental character, so far as this is possible, and to make it an equally accessible service function. The concept is illustrated in Figure 4, which describes a computer-oriented information system based on detailed customer demand forecasts; it services the needs of the representative production-inventory organization described in Figure 1. The corresponding information delays, listed as Table 2, show a marked improvement.

From an organizational standpoint, however, the most interesting change can be observed in the positioning of the divisional (or corporate) planning group with respect to the information flow. Instead of passing all data

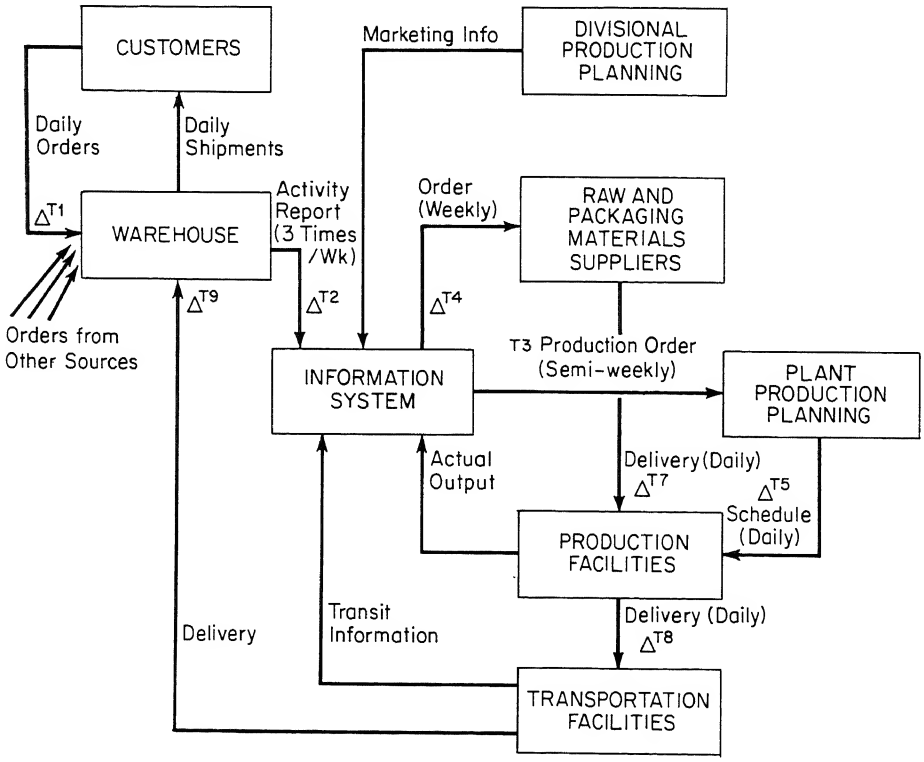


Figure 4

Information flow in a forecasting-oriented production-inventory system

TABLE 2

Information Delay Analysis (in Weeks)

Delay Symbol	*Explanation*	*Average Duration*	*Range*
ΔT_1	Orders placed for future delivery reflected in system	0	0
ΔT_2	Delay of reporting cycle	0.2	0 –0.4
	Reporting lag	0.1	0 –0.1
ΔT_3	Reporting lag—transmission of data	0	0
ΔT_4	Production scheduling administrative time	0.4	0.4–0.6
	Order placement with vendor	0	0 –0
ΔT_5	Manpower assignment time—union rules	0.6	0.4–0.6
ΔT_6	Rail-car availability planning	0.2	0.2–0.6
ΔT_7	Supplier delivery lead time	0	0
ΔT_8	Variation in scheduled output	0.1	0 –0.2
ΔT_9	Transit time	0.8	0.5–1.2
		2.4	1.5–3.7

through the centralized group for occasional modification as warranted, the information system now passes all forecasts without delay directly to decentralized production points.

In this process, facts from the local warehouses, as well as instructions describing the marketing plans, are within a few hours transformed by a computer into production forecasts and shipment dispatches. In other words, we have dispensed with delayed communications in two segments (ΔT_3) and substituted for them rapid information transfer from several points of origin simultaneously.

The same process is repeated in providing production forecasts to suppliers. Rather than waiting for clearance through the plant organization (ΔT_4), the information system simultaneously provides the plants' production forecasts in terms of raw and packaging materials usage to individual major suppliers after making allowances for all goods in transit, as well as for all safety stocks required at the user plants.

The major advantage of the integrated management information system over a more conventional method of operation is that it permits the investment of all forecasting know-how at a single location for ready distribution to everyone. Hence more money can be spent in perfecting the single source of forecasts as contrasted with diluted efforts resulting when two or more organizational units attempt to develop partial approaches to the problem of anticipating each other's needs. Consolidated forecasting can also materially aid in eliminating a certain amount of organizational friction because it carries within itself the guarantee that everyone will base plans and action on identical assumptions about the future.

When information delays shown in Table 1 are compared with those in Table 2, it becomes evident that the most significant improvement through information system design based on forecasting can be found less in the decreased average reaction time (a reduction from 5.9 weeks to 2.4 weeks) than in the markedly improved precision with which a well-designed information system operates. For a consumer-oriented enterprise, the maximum reaction time to a change in the competitive environment will most

likely be a significant yardstick for measurement of good performance. For this reason, the change in this characteristic (as illustrated by a decrease from a maximum delay of 11.9 weeks to 3.7) is particularly worthy of attention, because the reflexes of an organization with maximum delays close to the average delays can be predicted with greater accuracy.

It can also be said that a production and distribution organization not possessing such a high degree of predictability invariably invites the creation of expediting staffs. They must necessarily receive a variety of information and, in turn, forecast how and when a specially handled item should be produced and delivered. Hence, from the standpoint of overall information system design, communication to and from expediters very rapidly complicates data handling. Such complexity may actually aggravate the condition which it has set out to cure, particularly if it involves the creation of coordinating staff groups through which certain priorities must be cleared. The expediting group may indeed shorten the minimum reaction time of a complex production process. On the other hand, only a thorough information system analysis with particular emphasis on the effects of such an expediting body on overall predictability would reveal whether the expediters themselves do not actually create the need for additional coordinating personnel.

When starting work on business forecasting it is necessary to define carefully the desirable level of aggregation at which the forecasts will have to be made as well as the cost consequences of such forecasts if they prove to be inaccurate.

Level of Aggregation

It is well known among commercial fishermen that if you are after big fish a net with small mesh is burdensome. On the other hand, herring cannot be caught with nets that have too large openings. Since the role of forecasting in management information systems can be likened to fishing in a sea of expected facts, it is important to design the forecasting "net" to fit its operational use and to make forecasts at an appropriate level of detail.

When designing an integrated information system, all the needs must be taken into account. The principal advantage of the system lies precisely in its capability to fully and consistently satisfy all informational needs. For this reason, subject to limitations of cost and availability of data, forecasting should take place at the lowest possible level of detail within the shortest forecasting cycle available. Consolidated (product line, divisional, corporate, etc.) forecasting should then be built up by synthesis of the detailed projections or by synthesis of detail data to serve as input into higher level forecasting models.

When adopting this approach, the information system designer will have to overcome strong pressures from management who may not be readily convinced of the need for extensive detail and who may be concerned about the increased margin of forecasting error at the lower levels of aggregation. The temptation to appear a good prophet may influence a system designer to take the easy route and produce longer term, consolidated forecasts which are invariably more accurate because they contain a variety of data which have already built in compensating influences arising from averaging of basic data.

How to Communicate about Forecasts

The presentation technique and format of forecasting information places appreciable demands on the ingenuity of an information system designer. The

personnel costs associated with the administration of the system will bear some relationship to the effectiveness with which the results obtained through the system are communicated and displayed.

A sales forecast in the hands of a production scheduler at a plant is not by itself particularly meaningful. The scheduler addresses himself chiefly to questions that are narrowly focused around the functions of his job: *when* to produce, and *how much*. To answer these questions, the sales forecast must be adjusted to reflect inventories, goods in process, and goods in transit. Further allowances must be made for transit lead time, safety stock levels desired, economic production quantities, provision for seasonal inventory buildups, and for pending marketing promotions. This involves extensive computations to transform a sales forecast into a simple computer output which will allow the scheduler to scan the system's recommendations in terms that are meaningful to his frame of reference, such as the latest allowable calendar dates when the production may begin without jeopardizing the desired levels of customer service.[8]

Insofar as presentation of computer output is concerned, misdirected emphasis is mainly due to one of the two typical biases: (1) the accountant's bias and (2) the operations researcher's bias.

The Accountant's Bias

An analyst with heavy accounting systems background invariably designs the reporting format by resorting to full print-out of all detailed data, in columnar format. With all facts thus displayed, heavy reliance is placed on the user's judgment to arrive at decisions. Such reporting may be adequate and provide the basis for making a planning decision, but as the frequency of reporting increases and approaches real-time decision-making, the "full facts tabulation" method becomes too burdensome and the recipients of reports reach their human limit for absorbing the contents of computer-generated reports.

The Operations Researcher's Bias

An information system designer with a mathematician's point of view is inclined to produce reports which focus on the limitations of the mathematical model used in the various computations. This approach to the presentation of results has important uses particularly if the scheduling decisions are infrequent or if they involve major commitment of resources. The "business model" oriented outputs also have important uses in analyzing broad policy alternatives in plant scheduling. However, the typical production scheduler is task oriented, pressed for time. He will gladly delegate the analysis to staff specialists. In the fast world of everyday decisions, the finer points of forecasting models are of little interest to the user. If the tendency to display mathematical backup information is carried to an extreme, it will slow down appreciably the acceptance by line personnel of computer-oriented management information systems.

Ideally, the presentation technique built into a management information system based on computers should reflect both the accountant's bias toward elaborate tabulation of facts and the operations researcher's concern about limitations of mathematical models. An information system should be capable of generating a large variety of each type of these reports but only upon request rather than as a matter of reporting routine.

[8] For an example of such a calendarized index see Paul A. Strassmann, "A Plant-Warehouse System Using Variable Lead Times & Reorder Times," *Management Technology* (August, 1962).

A corollary concept to this striving for economy in reporting is the idea that each organizational level should have the capability to assess the information system in terms of its particular functions. The relevant time span of decisions and the appropriate level of detail answering the questions *when* and *how much* are different when asked by a transportation dispatcher or by a purchasing agent.

The practical business world, in short, calls for a highly diversified capability to generate a variety of reports about the consequences of business forecasts. Inasmuch as the precise organizational relationships and skill levels of all recipients of forecasting information cannot be preplanned during system design, the computer system should be constructed to allow easy modification of the scope and format of all information produced for management uses.

Forecasting by Opinion

Mathematical and statistical forecasting techniques are of little use when dealing with customer demand patterns that are unique or timed without relationship to prior historical experience. In point is the product movement resulting from trade promotions, customer premium offers, concentrated advertising campaigns, or new product introductions. The demand pattern for such practices is characterized by its deliberate starting date, preplanned duration, and overall demand level, somehow related to the intensity or effectiveness of the promotional activity.

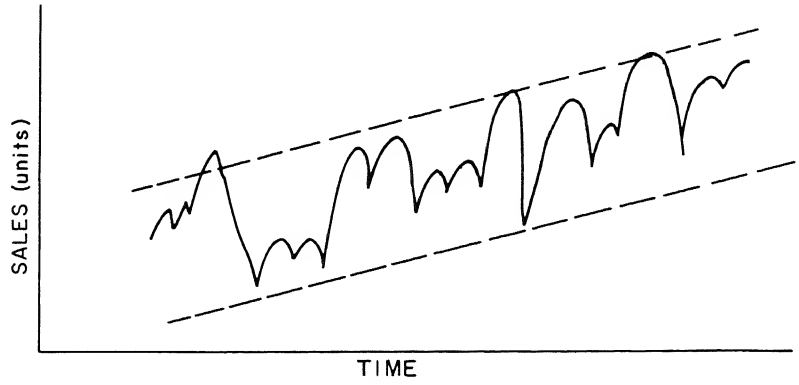
Figure 5 illustrates the sales pattern for a product possessing certain probabilistic properties, that seemingly lends itself to statistical forecasting techniques, and the sales curve for a heavily promoted item. We can still chose to apply forecasting methods, such as exponential smoothing, to the latter demand pattern, with the consequence that relatively large forecasting errors will develop. However, if forecasting errors are expensive, as they frequently are for reasons discussed earlier, the designer of a management information system may have no choice but to find a way for incorporating the intelligence about the pending promotional activity into the overall flow of data.

The starting date, location, scope, type, and duration of a particular promotional activity are usually known to the sales force because considerable planning must precede the successful launching of a campaign. Capturing the information in a definitive form and at an authoritative source will be in itself a major accomplishment, even though this data often represents only estimates rather than facts. For example, the effective duration of a promotion will be only an expression of opinion by the sales force rather than a statistically determinable forecast.

The total short-term incremental volume increase (see Area A in Figure 5) that is assignable to a particular type of promotion is much harder to forecast. Certain types of activity, such as X cents "off-label" sales, are reasonably well estimated by experienced sales executives. Other activities, such as the introduction of new or improved products, are seldom well estimated even by seasoned judgment reinforced by marketing research.

When considered as an intraorganizational communications problem, the important factor may not at all be the degree of accuracy of the incremental volume estimate assignable to the marketing promotion but the information handling problems. They can contribute even more significantly to the maximum reaction delay of an organization than forecasting errors.

At General Foods a technique has



Statistical sales pattern

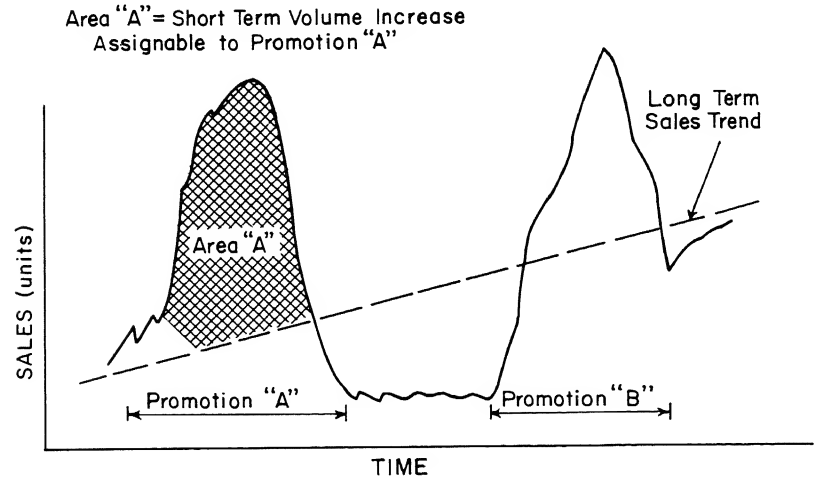


Figure 5
Sales pattern for a highly promoted item

been devised for injecting the salesmen's estimates of short-term effects of promotional activities into the overall flow of data. Several hundred such judgments are contained within the information system at any time.

As input to the system, coded entries are received containing pertinent geographic and production information and anticipated changes in the long-term sales trend. The new information is then matched against a detailed historical file containing the week-to-week sales rate of all prior promotions of a similar type in the same sales district.[9]

A computer program now performs a series of computations which make an allowance for dissimilar lengths of promotional campaigns in the past and the present, relative intensity indexes of promotional efforts in the past and the present, etc. The result is a series

[9] For further detail see the author's paper "Managerial Problems in Designing and Organizing a Computer System for Inventory Control," Proceedings of the Food Industries Symposium, IBM Corporation, Endicott, N. Y., 1963.

of weighted factors representing a mix of historical facts tempered by current judgment which are, in turn, entered into exponential smoothing mathematical equations expressing the long-term sales trend for the promoted item. The short-term "promotional" factors, so to speak, override the long-term pattern and produce detailed weekly shipment schedule estimates for the entire promotional period.

The exponential smoothing techniques can be further utilized for the improvement of the entire forecasting process after the promotional period has passed. A series of computer routines has been provided that analyze the actual shape of the short-term promotional activity and compare it to the one which was originally forecast. The computer program is equipped with the facility to reflect the relative weight of each completed promotion on all the historical records of prior promotional activity. Thus, the latest experience can be brought to bear its effect on new forecasts under controlled conditions.

It is too early to make broad generalizations about the relevance of judgmental estimates as an important input into management information systems. The resistance to using this approach stems from well-founded arguments that a computer system is only as good as its input. Hence, the orthodox approach to systems design calls for meticulous verification of all incoming data that should, so far as possible, tie in with records maintained as an integral part of conducting the business: Executive judgment is, therefore, excluded from a reporting system.

It cannot be denied that such conservatism is well founded if the system design is concerned primarily with the recording of the past or with reactions to presently incoming information—be it customer orders, shipping advices, airline reservations, or stock market purchases. If, however, the role of management information systems in planning and coordination of future events is to grow, an executive's judgment somehow will have to be tapped and translated into coded form so that full implications of his views will be available for rapid dissemination throughout the information system. It seems that one of the important areas for tempering extrapolated facts with judgment lies precisely in the field of forecasting, where complex interactions between a firm and its environment may be best expressed by attaching quantitative value expressions to the executive's feeling of optimism or pessimism.

The alternative to this approach remains in the continued reliance on communicating the intensity of the executive's feelings through a number of informational channels and reporting levels. Wherever the relative efficiency, speed and undeniable flexibility of such communications serve adequately the needs of an organization, a more formal approach is not necessary. However, if the environment changes rapidly and results in a need for continuous reassessment of short-term forecasts, which in turn is attended by costly practices, then the incorporation of judgmental forecasts may provide a marked improvement in serving the communicating needs of the enterprise.

Conclusion and Summary

When designing a management information system, the role of forecasting in it must be carefully assessed. The ability to forecast short-term customer demand and then rapidly distribute this information throughout the organization so as to obtain an optimal reaction to a change in a firm's competitive

environment is seen as one of the primary objectives in the use of forecasting. To attain such an objective, forecasting must be done at a sufficiently low level of detail and forecast results should be communicated to all personnel in a format oriented toward the decisions which must be made.

Forecasting of customer demand for a product is the principal unknown factor in business planning. Therefore, a concerted effort toward unified forecasting should be made. The cost effects of forecasts, modified by passage through several organizational levels, can be identified through an analysis of the average and maximum informational delays traced by the flow of paperwork.

It is further suggested that complete reliance on a variety of mathematical forecasting techniques will not adequately meet the needs of business organizations engaged in vigorous promotional activities. Executive judgment must be a significant design concept of the information system.

Better forecasting within integrated management information systems may, in the future, be assigned an important cost reduction mission and serve as one means by which increasing demands for better service and changed products are met. The increased production and distribution costs associated with unpredictable customer demand patterns can in large part be offset by improved handling of information.

MULTIPLE REGRESSION ANALYSIS OF COST BEHAVIOR

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Information concerning the variability of cost with output and other decision variables is needed in a large number of managerial analyses. Multiple regression analysis is a valuable cost measurement tool particularly for recurring decisions. Data requirements related to (1) the length, (2) the number of time periods, (3) the range of observations, and (4) the specification of cost-related factors are described and implications for cost recording are outlined as well. The functional form of the regression equation is presented and followed by an illustration.

Accountants probably have always been concerned with measuring and reporting the relationship between cost and output. The pre-eminence of financial accounting in this century resulted in directing much of our attention toward attaching costs to inventories. However, the recent emphasis on decision making is causing us to consider ways of measuring the variability of

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cost with output and other decisions variables. In this paper, the application, use, and limitations of multiple regression analysis, a valuable tool for measuring costs, are discussed.[1]

A valid objection to multiple regression analysis in the past has been that its computational difficulty often rendered it too costly. Today, with high speed computers and library programs, this objection is no longer valid: Most regression problems ought to cost less than $30 to run. Unfortunately, this new ease and low cost of using regression analysis may prove to be its undoing. Analysts may be tempted to use the technique without adequately realizing its technical data requirements and limitations. The "GI-GO" adage, "garbage in, garbage out," always must be kept in mind. A major purpose of this paper is to state these requirements and limitations explicitly and to indicate how they may be handled.

The general problem of cost measurement is discussed in the first section of this paper. Multiple regression analysis is considered first in relation to other methods of cost analysis. Then its applicability to cost decision problems is delineated. Second, the method of multiple regression is discussed in nonmathematical terms so that its uses can be understood better. The third section represents the "heart" of the paper. Here the technical requirements of multiple regression are outlined, and the implications of these requirements for the recording of cost data in the firm's accounting records are outlined. The functional form of the regression equation is then considered. In the final section, we discuss some applications for multiple regression analysis.

[1] The use of statistical analysis for auditing and control is outside the scope of this paper. Excellent discussions of these uses of statistics may be found in Richard N. Cyert and H. Justin Davidson, *Statistical Sampling for Accounting Information* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962); and Herbert Arkin, *Handbook of Sampling for Auditing and Accounting*, Vol. I: *Methods* (New York: McGraw-Hill Book Company, 1963).

The General Problem

In his attempts to determine the factors that cause costs to be incurred and the magnitudes of their effects, the accountant is faced with a formidable task. Engineers, foremen, and others who are familiar with the production process being studied usually can provide a list of cost-causing factors, such as the number of different units produced, the lot sizes in which units were made, and so forth. Other factors that affect costs, such as the season of the year, may be important, though they are more subtle than production factors. The accountant must separate and measure the effects of many different causal factors whose importance may vary in different periods.

Commonly Used Methods of Cost Analysis

Perhaps the most pervasive method of analyzing cost variability is separation of costs into two or three categories: variable, fixed, and, sometimes, semivariable. But this method does not provide a solution to the problem of measuring the costs caused by each of many factors operating simultaneously. In this "direct costing" type of procedure, output is considered to be the sole cause of costs. Another objection to this method is that there is no way to determine whether the accountant's subjective separation of costs into variable and fixed is reasonably accurate. Dividing output during a period into

variable cost during that period yields a single number (unit variable cost), whose accuracy cannot be assessed. If the procedure is repeated for several periods, it is likely that different unit variable costs will be computed. But the accountant cannot determine whether the average of these numbers (or some other summary statistic) is a useful number. Another important shortcoming of this method is the assumption of linearity between cost and output. While linearity may be found, it should not be assumed automatically.

A variant of the fixed-variable method is one in which cost and output data for many periods are plotted on a two-dimensional graph. A line is then fitted to the data, the slope being taken as variable cost per unit of output. When the least-squares method of fitting the line is used, the procedure is called simple linear regression. Until the recent advent of computers, simple regression was considered to be quite sophisticated.[2] While it was recognized that its use neglects the effects on cost of factors other than output, it was defended on the then reasonable grounds that multiple regression with more than two or three variables is too difficult computationally to be considered economically feasible.

Multiple Regression

Multiple regression can allow the accountant to estimate the amount by which the various cost-causing factors affect costs. A very rough description is that it measures the cost of a change in one variable, say, output, while holding the effects on cost of other variables, say, the season of the year or the size of batches, constant. For example, consider the problem of analyzing the costs incurred by the shipping department of a department store. The manager of the department believes that his costs are primarily a function of the number of orders processed. However, heavier packages are more costly to handle than are lighter ones. He also considers the weather an important factor: Rain or extreme cold slows down delivery time. We might want to eliminate the effect of the weather, since it is not controllable. But we would like to know how much each order costs to process and what the cost of heavier against lighter packages is. If we can make these estimates, we can (1) prepare a flexible budget for the shipping department that takes account of changes in operating conditions, (2) make better pricing decisions, and (3) plan for capital budgeting more effectively. A properly specified multiple regression equation can provide the required estimates.

A criticism of multiple regression analysis is that it is complicated and so would be difficult to "sell" to lower management and supervisory personnel. However, the method allows for a more complete specification of "reality" than do simple regression or the fixed-variable dichotomy. Studies have shown that supervisors tend to disregard data that they believe are "unrealistic," such as those based on the simplification that costs incurred are a function of units of output only.[3] Therefore, multiple regression analysis should prove more acceptable to supervisors than procedures that require gross simplification of reality.

The regression technique also can allow the accountant to make probability statements concerning the relia-

[2] National Association of Accountants, *Separating and Using Costs as Fixed and Variable,* June, 1960.

[3] H. A. Simon, H. Guetzkow, G. Kozmetsky, and G. Tyndall, *Centralization versus Decentralization in Organizing the Controller's Department* (New York: The Controllership Foundation, 1954).

bility of the estimates made.[4] For example, he may find that the marginal cost of processing a package of average weight is $.756, when the effects on cost of different weather conditions and other factors are accounted for. If the properties underlying regression analysis (discussed below) are met, the reliability of this cost estimate may be determined from the standard error of the coefficient (say, $.032) from which the accountant may assess a probability of .95 that the marginal cost per package is between $.692 and $.820 ($.756 \pm .064$).

Multiple regression analysis, then, is a very powerful tool; however, it is not applicable to all cost situations. To decide the situations for which it is best used, let us first consider the problem of cost estimation in general and then consider the subclass of problems for which multiple regression analysis is useful.

Types of Cost Decision Problems

In general, cost is a function of many variables, including time. For example, the cost of output may be affected by such conditions as whether production is increasing or decreasing, the lot sizes are large or small, the plant is new or old, the White Sox are losing or winning, and so forth. Since there is *some* change in the environment of different time periods or in the circumstances affecting different decisions, it would seem that the accountant must make an individual cost analysis for every decision considered.

However, the maximization rule of economics also applies to information technology: The marginal cost of the information must not exceed the marginal revenue gained from it. The marginal revenue from cost information is the additional revenue that accrues or the losses that are avoided from not making mistakes, such as accepting contracts where the marginal costs exceed the marginal revenue from the work, or rejecting contracts where the reverse situation obtains. The marginal cost of information is the cost of gathering and presenting the information, plus the opportunity cost of delay, since measurement and presentation are not instantaneous.[5] Since these costs can be expected to exceed the marginal revenue from information for many decisions, it usually is not economical to estimate different costs for each different decision. Thus, it is desirable to group decision problems into categories that can be served by the same basic cost information. Two such categories are proposed here: (1) recurring problems and (2) one-time problems.

Recurring decision problems are those for which the data required for analysis are used with some regularity. Examples are determining the prices that will be published in a catalog, preparation of output schedules for expected production, the setting of budgets and production cost standards, and the formulation of forecasts. These decisions require cost data in the form of schedules of expected costs due to various levels of activity over an expected range.

One-time problems are those which occur infrequently, unpredictably, or are of such a magnitude as to require individual cost estimates. Examples of these problems are cost-profit-volume decisions, such as whether the firm

[4] This and the following statements are made in the context of a Bayesian analysis, in which the decision maker combines sample information with his prior judgment concerning unknown parameters. In the examples given, a jointly diffuse prior distribution is assumed for all parameters.

[5] These two costs are related since delay can be reduced by expending more resources on the information system.

should take a one-time special order; make, buy, or lease equipment; develop a new product; or close a plant. These decisions require that cost estimates be made which reflect conditions especially relevant to the problem at hand.

These categories present different requirements for cost estimation. Recurring problems require a schedule of *expected* costs and activity. Since these problems are repetitive, the marginal cost of gathering and presenting data each time usually is expected to be greater than the marginal revenue from the data. Thus, while the marginal cost of additional production, for example, will differ depending on such factors as whether overtime is required or excess capacity is available, in general, it is more profitable to estimate the amount that the marginal cost of the additional production may be, on the average, rather than to take account of every special factor that may exist in individual circumstances.

In contrast, one-time problems are characterized by the economic desirability of making individual cost estimates. We do not rely on average marginal costs because the more accurate information is worth its cost. This situation may occur when the problem is unique, and average cost data are therefore not applicable. Or the decision may involve a substantial commitment of resources, making the marginal revenue from avoiding wrong decisions quite high.

Multiple Regression Analysis

Regression analysis is particularly useful in estimating costs for recurring decisions.[6] The procedure essentially consists of estimating mathematically the *average* relationship between costs (the "dependent" variable) and the factors that cause cost incurrences (the "independent" variables). The analysis provides the accountant with an estimate of the expected marginal cost of a unit change in output, for example, with the effects on total cost of other factors accounted for. These are the data he requires for costing recurring decisions.

The usefulness of multiple regression analysis for recurring decisions of costs can be appreciated best when the essential nature of the technique is understood. It is not necessary that the mathematical proofs of least squares or the methods of inverting matrices be learned since library computer programs do all the work.[7] However, it is necessary that the assumptions underlying use of multiple regression be fully understood so that this valuable tool is not misused.

Multiple regression analysis presupposes a linear relationship between the contributive factors and costs.[8] The functional relationship between these factors, $x_1, x_2, \ldots, x_n$, and cost, C, is assumed in multiple regression analysis to be of the following form:

$$C_t = \beta_0 x_{0,t} + \beta_1 x_{1,t} + \beta_2 x_{2,t} + \cdots + \beta_n x_{n,t} + \mu_t, \qquad (1)$$

where

β_0 is a constant term ($x_0 = 1$ for all observations and time periods),

the β's are fixed coefficients that express the marginal contribution of each x_i to C, and

μ is the sum of unspecified factors, the disturbances, that are assumed to be randomly distributed with a

[6] Indeed, its use requires the assumption that the past costs used for a regressions analysis are a sample from a universe of possible costs generated by a continuing, stationary, normal process.

[7] The mathematics of multiple regression is described in many statistics and econometrics texts.

[8] A curvilinear or exponential relationship also can be expressed as a linear relationship. This technique is discussed below.

zero mean and constant variance, and

$t = 1, 2, \ldots, m$ = time periods.

The β coefficients are estimated from a sample of C's and x's from time periods 1 through m. For example, assume that the cost recorded in a week is a function of such specified factors as x_1= units of output, x_2=number of units in a batch, and x_3=the ratio of the number of "de luxe" units to total units produced. Then the right hand side of equation (2) is an estimate of the right hand side of equation (1), obtained from a sample of weekly observations, where the b's are estimates of the β's and u is the residual, the estimate of μ, the disturbance term:

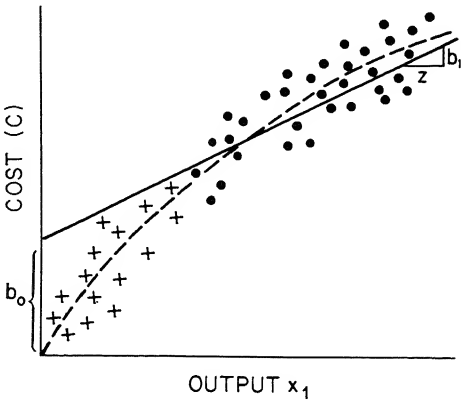
$$C_t = b_{0,t} + b_1 x_{1,t} + b_2 x_{2,t} + b_3 x_{3,t} + u_t. \qquad (2)$$

If the values estimated for coefficients of the three independent variables, x_1, x_2, and x_3, are $b_0=100$, $b_1=30$, $b_2=-20$, and $b_3=500$, the expected cost ($\hat{C}$) for any given week (t) is estimated by:

$$\hat{C} = 100 + 30x_1 - 20x_2 + 500x_3.$$

Given estimates of the β's, one has, in effect, estimates of the marginal cost associated with each of the determining factors. In the example given above, the marginal cost of producing an additional unit of output, x_1, is estimated to be \$30, with the effects or costs of the size of batch (x_2) and the ratio of the number of de luxe to total units (x_3) accounted for. Or, β_2, the marginal reduction in total cost of increasing the batches by 3 units, given fixed values of the number of units and the relative proportions of de luxe units produced, is estimated to be −\$60 (−\$20 times 3).

It is tempting to interpret the constant term, b_0, as fixed cost. But this is not correct unless the linear relationship found in the range of observations obtains back to zero output.[9] This can be seen best in the following two-dimensional graph of cost on output.



The line was fitted with the equation $C=b_0+b_1x_1$, where the dots are the observed values of cost and output. The slope of the line is the coefficient, b_1, an estimate of the marginal change in total cost (C) with a unit change (z) in output (x_1). The intercept on the C axis is b_0, the constant term. It would be an estimate of fixed cost if the range of observations included the point where output was zero, and the relationship between total cost and output was linear. However, if more observations of cost and output (the x's) were available, it might be that the dashed curve would be fitted and b_0 would be zero. Thus the value of the constant term, b_0, is not the costs that would be expected if there were no output; it is only the value that is calculated as a result of the regression line computed from the available data.

The data for the calculations are taken from the accounting and production records of past time periods. The coefficients estimated from these data are averages of past experience. Therefore, the b's calculated are best

[9] Fixed cost is defined here as avoidable cost related to time periods and not to output variables.

suited for recurring cost decisions. The fact that the b's are averages of past data must be emphasized, because their use for decisions is based on the assumption that the future will be like an average of past experience.

The mathematical method usually used for estimating the β's is the least-squares technique. It has the properties of providing best, linear, unbiased estimates of the β's. These properties are desirable because they tend "to yield a series of estimates whose average would coincide with the true value being estimated and whose variance about that true value is smaller than that of any other unbiased estimators."[10] While these properties are not always of paramount importance, they are very valuable for making estimates of the expected average costs required for recurring problems.

Another important advantage of the least-squares technique is that when it is combined with the assumptions about the disturbance term (μ_t) that are discussed in Section 7, below, the reliability of the relations between the explanatory variables and costs can be determined. Two types of reliability estimates may be computed. One, the standard error of estimate, shows how well the equation fits the data. The second, the standard error of the regression coefficients, assesses the probability that the β's estimated are within a range of values. For example, if a linear cost function is used, the coefficient (b_1) of output (x_1) is the estimated marginal cost of output. With an estimate of the standard error of the coefficient, s_{b_1}, we can say that the true marginal cost, β_1, is within the range $b_1 \pm s_{b_1}$, with a given probability.[11]

[10] J. Johnston, *Statistical Cost Analysis* (New York: McGraw-Hill Book Company, 1960), p. 31.

[11] The interpretation of the confidence interval is admittedly Bayesian.

Requirements of Multiple Regression and Cost Recording Implications

Although multiple regression is an excellent tool for estimating recurring costs, it does have several requirements that make its use hazardous without careful planning.[12] Most of the data requirements of multiple regressions analysis depend on the way cost accounting records are maintained. If the data are simply taken from the ordinary cost accounting records of the company, it is unlikely that the output of the regression model will be meaningful. Therefore, careful planning of the extent to which the initial accounting data are coded and recorded is necessary before regression analysis can be used successfully. This section of the paper is organized into four groupings that include several numbered subsections in which the principal technical requirements are described, after which the implications for the cost system are discussed. In the first group, (1) the length and (2) number of time periods, (3) the range of observations, and (4) the specification of cost-related factors are described, following which their implications for cost recording are outlined. In the second group, (5) errors of measurement and their cost recording implication are considered. The third group deals with (6) correlations among the explanatory variables and the important contribution that accounting analysis can make to this problem. Finally, (7) the requirements for the distribution of the nonspecified factors (disturbances) are given. The

[12] Proofs of the requirements described may be found in many econometrics textbooks, such as Arthur S. Goldberger, *Econometric Theory* (New York: John Wiley & Sons, Inc., 1964); and J. Johnston, *Econometric Methods* (New York: McGraw-Hill Book Company, 1963).

implications of these requirements for the functional form of the variables are taken up in the final section.

1. Length of Time Periods

a. The time periods (1, 2, 3, . . ., m) chosen should be long enough to allow the bookkeeping procedures to pair output produced in a period with the cost incurred because of the production. For example, if 500 units are produced in a day, but records of supplies used are kept on a weekly basis, an analysis of the cost of supplies used cannot be made with shorter than weekly periods. Lags in recording costs must be corrected or adjusted. Thus, production should not be recorded as occurring in one week while indirect labor is recorded a week later when the pay checks are written.

b. The time periods chosen should be *short* enough to avoid variations in production within the period. Otherwise, the variations that occur during the period will be averaged out, possibly obscuring the true relationship between cost and output.

2. Number of Time Periods (Observations)

For a time series, each observation covers a time period in which data on costs and output and other explanatory variables are collected for analysis. As a minimum, there must be one more observation than there are independent variables to make regression analysis possible. (The excess number is called "degrees of freedom.") Of course, many more observations must be available before one could have any confidence that the relationship estimated from the sample reflects the "true" underlying relationship. The standard errors, from which one may determine the range within which the true coefficients lie (given some probability of error), are reduced by the square root of the number of observations.

3. Range of Observations

The observations on cost and output should cover as wide a range as possible. If there is very little variation from period to period in cost and output, the functional relationship between the two cannot be estimated effectively by regression analysis.

4. Specification of Cost-Related Factors

All factors that affect cost should be specified and included in the analysis.[13] This is a very important requirement that is often difficult to meet. For example, observations may have been taken over a period when input prices changed. The true relationship between cost and output may be obscured if high output coincided with high input due to price-level effects. If the higher costs related to higher price levels are not accounted for (by inclusion of a price index as an independent variable) or adjusted for (by stating the dependent variable, cost, in constant dollars), the marginal cost of additional output estimated will be meaningful only if changes in input prices are proportional to changes in output and are expected to remain so.

Implications for Cost Recording of 1, 2, 3, and 4

In general, the time period requirements (1a, 1b, and 2) call for the recording of production data for peri-

[13] Complete specification is not mandatory if requirement 7 (below) is met. However, requirement 7 is not likely to be fulfilled if the specification is seriously incomplete.

ods no longer than one month and preferably as short as one week in length. If longer periods are chosen, it is unlikely that there will be a sufficient number of observations available for analysis because, as a bare minimum, one more period than the number of explanatory variables is needed. Even if it is believed that only one explanatory variable (such as units of output) is needed to specify the cost function in any one period, requirement 4 (that all cost-related factors be specified) demands consideration of differences among time periods. Thus, such events as changes in factor prices and production methods, whether production is increasing or decreasing, and the seasons of the year might have to be specified as explanatory variables.

The necessity of identifying all relevant explanatory variables, such as those just mentioned, can be met by having a journal kept in which the values or the behavior of these variables in specific time periods is noted. If such a record is not kept, it will be difficult (if not impossible) to recall unusual events and to identify them with the relevant time periods, especially when short time periods are used. For example, it is necessary to note whether production increased or decreased substantially in each period. Increases in production may be met by overtime. However, decreases may be accompanied by idle time or slower operations. Thus, we would expect the additional costs of increases to be greater than the cost savings from decreases.[14]

[14] A dummy variable can be used to represent qualitative variables, such as $P = 1$ when production increased and $P = 0$ when production decreased. From the coefficient of P, we can estimate the cost effect of differences in the direction of output change and also reduce contamination of the coefficient estimated for output.

Other commonly found factors that affect costs are changes in technology, changes in capacity, periods of adjustment to new processes or types of output, and seasonal differences. The effect of these factors may be accounted for by including variables in the regression equation, by specific adjustment of the data, or by excluding data that are thought to be "contaminated."

The wide range of observations needed for effective analysis also argues against observation periods of longer than one month. With long periods, variations in production would more likely be averaged out than if shorter periods were used (which violates requirement 1b). In addition, if stability of conditions limits the number of explanatory variables other than output that otherwise would reduce the degrees of freedom, this same stability probably would not produce a sufficient range of output to make regression analysis worthwhile. Thus, weekly or monthly data usually are required for multiple regression.

5. *Errors of Measurement*

It is difficult to believe that data from a "real life" production situation will be reported without error. The nature of the errors is important since some kinds will affect the usefulness of regression analysis more than others will. Errors in the dependent variable, cost, are not fatal since they affect the disturbance term, μ.[15] The predictive value of the equation is lessened, but the estimate of marginal cost (β_1) is not affected.

But where there are errors in measuring output or the other independent

[15] Let γ stand for the measurement errors in C:

$$C + \gamma = \beta_0 + \beta_1 x_1 + \mu$$
$$C = \beta_0 + \beta_1 x_1 + \mu - \gamma.$$

variable (x's), the disturbance term, μ, will be correlated with the independent variables.[16] If this condition exists, the sample coefficient estimated by the least-squares procedure will be an underestimate of the true marginal cost. Thus, it is very important that the independent variables be measured accurately.

The possibility of measurement errors is intensified by the number of observations requirement. Short reporting periods increase the necessity for careful classification. For example, if a cost caused by production in week 1 is not recorded until week 2, the dependent variable (cost) of both observations will be measured incorrectly. This error is most serious when production fluctuates between observations. However, when production is increasing or decreasing steadily, the measurement error tends to be constant (either in absolute or proportional terms) and hence will affect only the constant term. The regression coefficients estimated, and hence the estimates of average marginal cost, will not be affected.[17]

Another important type of measurement error is the failure to charge the period in which production occurs with future costs caused by that production. For example, overtime pay for production workers may be paid for in the week following their work. This can be adjusted for easily. However, the foreman may not be paid for his overtime directly. Rather, many months after his work he might get a year-end bonus or a raise in pay. These costs cannot easily be associated with the production that caused them but will be charged in another period, thus making both periods' costs incorrect.[18] This type of error is difficult to correct. Usually, all that one can do is eliminate the bonus payment from the data of the period in which it is paid and realize that the estimated coefficient of output will be biased downward. Average marginal costs, then, will be understated.

A somewhat similar situation follows from the high cost of the careful record keeping required to charge such input factors as production supplies to short time periods. In this event, these items of cost should be deducted from the other cost items and not included in the analysis. If these amounts are large enough, specific analysis may be required, or the decision not to account for them carefully may be re-evaluated.

This separation of specific cost items also is desirable where the accountant knows that their allocation to time periods bears no relation to production. For example, such costs as insurance or rent may be allocated to departments on a monthly basis. There is no point in including these costs in the dependent variable because it is known that they do not vary with the independent variables. At best, their inclusion will only increase the constant term. However, if by chance they are correlated with an independent variable, they will bias the estimates made (requirement 7a). This type of error may be built into the accounting system if fixed costs are allocated to time periods on the basis of production. For example, depreciation may be charged on a per unit basis. The variance of this cost, then, may be a

[16] In this event, where ψ stands for the measurement error in x_1:

$$C = \beta_0 + \beta_1(x_1 + \psi) + \mu$$
$$C = \beta_0 + \beta_1 x_1 + \mathrm{B}_1\psi + \mu.$$

The new disturbance term $\beta_1\psi + \mu$, is not independent of x_1 because of the covariance between these variables.

[17] If the error is proportionally constant (i.e., 10 per cent of production), transformation of the variables (such as to logarithms) is necessary.

[18] Actually, the present value of the future payment should be included as a current period cost.

function of the accounting method and not of the underlying economic relationships.[19]

6. *Correlations among the Explanatory (Independent) Variables*

When the explanatory variables are highly correlated with one another, it is very difficult, and often impossible, to estimate the separate relationships of each to the dependent variable. This condition is called multicollinearity, and it is a severe problem for cost studies. When we compute marginal costs, we usually want to estimate the marginal cost of *each* of the different types of output produced in a multiproduct firm. However, this is not always possible. For example, consider a manufacturer who makes refrigerators, freezers, washing machines, and other major home appliances. If the demand for all home appliances is highly correlated, the number of refrigerators, freezers, and washing machines produced will move together, all being high in one week and low in another. In this situation it will be impossible to disentangle the marginal cost of producing refrigerators from the marginal cost of producing freezers and washing machines by means of multiple regression.[20]

Problems similar to that of our manufacturer can be alleviated by disaggregation of total cost into several subgroups that are independent of each other. Preanalysis and preliminary allocations of cost and output data may accomplish this disaggregation. This is one of the most important contributions the accountant can make to regression analysis.

If the total costs of the entire plant are regressed on outputs of different types, it is likely that the computed coefficients will have very large standard errors and, hence, will not be reliable. This situation may be avoided by first allocating costs to cost centers where a single output is likely to be produced. This allows a set of multiple regressions to be computed, one for each cost center. The procedure (which may be followed anyway for inventory costing) also reduces the number of explanatory variables that need be specified in any one regression.[21] Care must be taken to assure that the allocation of costs to cost centers is not arbitrary or unrelated to output. For example, allocation of electricity or rent on a square footage basis can serve no useful purpose. However, allocation of the salary of the foremen on a time basis is necessary when they spend varying amounts of time per period supervising different cost centers.

A further complication arises if several different types of outputs are produced within the cost centers. For example, the assembly department may work on different models of television sets at the same time. In most instances, it is neither feasible nor desirable to allocate the cost center's costs to each type of output. Cost, then, should be regressed on several output variables, one for the quantity of each type of output. If these independent variables are multicollinear, the standard errors of their regression coefficients will be so large relative to the coefficients as to make the

[19] Depreciation is assumed to be time, not user, depreciation.

[20] However, the computed regression can provide useful predictions of total costs if the past relationships of production among the different outputs are maintained.

[21] The author used this procedure with considerable success in estimating the marginal costs of banking operations. See George J. Benston, "Economies of Scale and Marginal Costs in Banking Operations," *National Banking Review* (1965), 507–49.

estimates useless. In this event, an index of output may be constructed in which the different types of output are weighted by a factor (such as labor hours) that serves to describe their relationship to cost. Cost then may be regressed on this weighted index. The regression coefficient computed expresses the average relationship between the "bundle" of outputs and cost and cannot be decomposed to give the relationship between one output element and cost. However, since the outputs were collinear in the past, it is likely that they will be collinear in the future, so that knowledge about the cost of the "bundle" of outputs may be sufficient.

A valid objection to the allocation of costs to cost centers is that one can never be sure that the allocations are accurate. Nevertheless, some allocations must be made for multicollinearity to be overcome. Therefore, the statistical method cannot be free from the accountant's subjective judgment; in fact, it depends on it.

A limitation of analysis of costs by cost centers also is that cost externalities among cost centers may be ignored. For example, the directly chargeable costs of the milling department may be a function of the level of operations of other departments. The existence and magnitude of operations outside of a particular cost center may be estimated by including an appropriate independent variable in the cost center regression. An overall index of production, such as total direct labor hours on total sales, is one such variable. Or, if a cost element is allocated between two cost centers, the output of one cost center may be included as an independent variable in the other cost center's regressions. The existence and effect of these possible intercost center elements may be determined from the standard error of the coefficient and sign of this variable.

Some types of costs that vary with activity cannot be associated with specific cost centers because it is difficult to make meaningful allocations or because of bookkeeping problems (as discussed above). In this event, individual regression analyses of these costs probably will prove valuable. For example, electricity may be difficult to allocate to cost centers although it varies with machine hours.[22] A regression can be computed such as the following:

$$E = b_0 + b_1M + b_2S_1 + b_3S_2 + b_4S_3 \qquad (3)$$

where

E = electricity cost
M = total machine hours in the plant
S = seasonal dummy variables

where

S_1 = 1 for summer, 0, for other seasons
S_2 = 1 for spring, 0 for other seasons
S_3 = 1 for winter, 0 for other seasons

b_0, b_1, b_2, b_3, and b_4 are the computed constants and coefficients.

If the regression is fully specified, with all factors that cause the use of electricity included (such as the season of the year), the regression coefficient of M, b_1, is the estimate of the average marginal cost of electricity per machine hour. This cost can be added to the other costs (such as materials and labor) to estimate the marginal cost of specific outputs.

For some activities, physical units such as labor hours can be used as the dependent variable instead of costs. This procedure is desirable where most of the activity's costs are a function of such physical units and where factor prices are expected to vary. Thus, in a

[22] Machine hours may not be recorded by cost center although direct labor hours are. If machine hours (M) are believed to be proportional to direct labor hours (L), so that $M_i = k_iL_i$, where k is a constant multiplier that may vary among cost centers, i, k_iL_i is a perfect substitute for M_i.

shipping department, it may be best to regress hours worked on pounds shipped, percentage of units shipped by truck, the average number of pounds per sale, and other explanatory variables. Then, with the coefficients estimated, the number of labor hours can be estimated for various situations. These hours then can be costed at the current labor rate.

7. *Distribution of the Nonspecified Factors (Disturbances)*

a. Serial Correlation of the Disturbances. A very important requirement of least squares that affects the coefficients and the estimates made about their reliability is that the disturbances not be serially correlated. For a time series (in which the observations are taken at successive periods of time), this means that the disturbances that arose in a period t are independent of the disturbances that arose in previous periods, t-1, t-2, etc. The consequences of serial correlation of the disturbances are that: (1) the standard errors of the regression coefficients (b's) will be seriously underestimated, (2) the sampling variances of the coefficients will be very large, and (3) predictions of cost made from the regression equation will be more variable than is ordinarily expected from least-squares estimators. Hence, the tests measuring the probability that the true marginal costs and total costs are within a range around the estimates computed from the regression are not valid.

b. Independence from Explanatory Variables. The disturbances which reflect the factors affecting cost that cannot be specified must be uncorrelated with the explanatory (independent) variables. $(x_1, x_2, \ldots, x_n)$. If the unspecified factors are correlated with the explanatory variables, the coefficients will be biased and inconsistent estimates of the true values. Such correlation often is the result of bookkeeping procedures. For example, repairs to equipment in a machine shop is a cost-causing activity that often is not specified because of quantification difficulties. However, these repairs may be made when output is low because the machines can be taken out of service at these times. Thus, repair costs will be negatively correlated with output. If these costs are not separated from other costs, the estimated coefficient of output will be biased downward, so that the true extent of variableness of cost with output will be masked.

c. Variance of the Disturbances. A basic assumption underlying use of least squares is that the variance of the disturbance term is constant; it should not be a function of the level of the dependent or independent variables.[23] If the variance of the disturbance is nonconstant, the standard errors of the coefficients estimated are not correct and the reliability of the coefficients cannot be determined.

When the relationship estimated is between only one independent variable (output) and the dependent variable (cost), the presence of nonconstant variance of the disturbances can be detected by plotting the independent against the dependent variable. However, where more than one independent variable is required, such observations cannot be easily made. In this event, the accountant must attempt to estimate the nature of the variance from other information and then transform the data to a form in which constant variance is achieved. At the least, he should decide whether the disturbances are likely to bear a proportional relationship to the other variables (as is commonly the situation with economic data). If they do, it may be desirable to transform the variables

23 Constant variance is known as homoscedasticity. Nonconstant variance is called heteroscedasticity.

to logarithms. The efficacy of the transformations may be tested by plotting the independent variables against the residuals (the estimates of the disturbances).

d. NORMAL DISTRIBUTION OF THE DISTURBANCES. For the traditional statistical tests of the regression coefficients and equations to be strictly valid, the disturbances should be normally distributed. Tests of normality can be made by plotting the residuals on normal probability paper, an option available in many library regression programs. While requirement 7 does not have implications for the accounting system, it does determine the form in which the variables are specified. These considerations are discussed in the following section.

Functional Form of the Regression Equation

Thus far we have been concerned with correct specification of the regression equation rather than with its functional form. However, the form of the variables must fit the underlying data well and be of such a nature that the residuals are distributed according to requirement 7 above.

The form chosen first should follow the underlying relationship that is thought to exist. Consider, for example, an analysis of the costs (C) of a shipping department. Costs may be a function of pounds shipped (P), percentage of pounds shipped by truck (T), and the average number of pounds per sale (A). If the accountant believes that the change in cost due to a change of each explanatory variable is unaffected by the levels of the other explanatory variables, a linear form could be used, as follows:

$$C = a + bP + cT + dA. \qquad (4)$$

In this form, the estimated marginal cost of a unit change in pounds shipped (P) is $\partial C/\partial P$ or b.

However, if the marginal cost of each explanatory variable is thought to be a function of the levels of the other explanatory variables, the following form would be better:

$$C = aP^bT^cA^d. \qquad (5)$$

In this case, a linear form could be achieved by converting the variable to logarithms:

$$\log C = \log a + b \log P + c \log T + d \log A. \qquad (6)$$

Now, an approximation to the expected marginal cost of a unit change in pounds shipped (P) is $\partial C/\partial P = baP^{b-1}\,\overline{T}^c\overline{A}^d$, where the other explanatory variables are held constant at some average values (denoted by bars over the letters). Thus, the estimated marginal cost of P is a function of the levels of the other variables.

The logarithmic form of the variables also allows for estimates of nonlinear relationships between cost and the explanatory variables. The form of the relationships may be approximated by graphing the dependent variable against the independent variable. (The most important independent variable should be chosen where there is more than one, although in this event the simple two-dimensional plotting can only be suggestive.) If the plot indicates that a nonlinear rather than a linear form will fit the data best, the effect of using logarithms may be determined by plotting the data on semi-log and log-log ruled paper.

If the data seem curvilinear even in logarithms, or if an additive rather than a multiplicative form describes the underlying relationships best, polynomial forms of the variables may be used. Thus, for an additive relationship between cost (C) and quantity of output (Q), the form fitted may be $C=$

$a+bQ+cQ^2+dQ^3$. If a multiplicative relationship is assumed, the form may be $\log C=\log a+\log Q+(\log Q)^2$. Either form describes a large family of curves with two bends.

When choosing the form of the variables, attention must always be paid to the effect of the form on the residuals, the estimates of the disturbances. Unless the variance of the residuals is constant, not subject to serial correlation, and approximately normally distributed (requirement 5), inferences about the reliability of the coefficients estimated cannot be made. Graphing is a valuable method for determining whether or not these requirements are met. (The graphs mentioned usually can be produced by the computers.) Three graphs are suggested. First, the residuals should be plotted in time sequence. They should appear to be randomly distributed, with no cycles or trends.[24] Second, the residuals can be plotted against the predicted value of the dependent variable. There should be as many positive or negative residuals scattered evenly about a zero line, with the variance of the residuals about the same at any value of the predicted dependent variable. Finally, the residuals should be plotted on normal probability paper to test for normality.

If the graphs show that the residuals do not meet the requirements of least squares, the data must be transformed. If serial correlation of the residuals is a problem, transformation of the variables may help. A commonly used method is to compute first differences, in which the observation from period t, $t-1$, $t-2$, $t-3$, etc., are replaced with $t-(t-1)$, $(t-1)-(t-2)$, $(t-2)-(t-3)$, and so forth. With first difference data, one is regressing the change in cost on the change in output, etc., a procedure which in many instances may be descriptively superior to other methods of stating the data. However, the residuals from first difference data also must be subjected to serial correlation tests, since taking first differences often results in negative serial correlations.[25]

When nonconstant variance of the residuals is a problem, the residuals may increase proportionally to the predicted dependent variables. In this event transformation of the dependent variable to logarithms will be effective in achieving constant variance. If the residuals increase more than proportionately, the square root of the dependent variable may be a better transformation.

An Illustration

Assume that a firm manufactures a widget and several other products, in which the services of several departments are used. Analysis of the costs of the assembly department will provide us with an illustration. In this department, widgets and another product, digits, are produced. The widgets are assembled in batches, while the larger digits are assembled singly. Weekly observations on cost and output are taken and punched on cards. A graph is prepared, from which it appears that a linear relationship is present. Further, the cost of producing widgets is not believed to be a function of the produc-

[24] A more formal test for serial correlation is provided by the Durbin-Watson statistic, which is built into many library regression computer programs. [J. Durbin, and G. J. Watson, "Testing for Serial Correlation in Least-Squares Regression," Parts I and II, *Biometrika* (1950 and 1951).]

[25] If there are random measurement errors in the data, observations from period $t-1$ might be increased by a positive error. Then $t-(t-1)$ will be lower and $(t-1)-(t-2)$ will be higher than if the error were not present. Consequently, $t-(t-1)$ and $(t-1)-(t-2)$ will be negatively serially correlated.

tion of digits or other explanatory variables. Therefore, the following regression is computed:

$$\begin{aligned}\hat{C} = {} & 110.3 + 8.21N - 7.83B \\ & \quad (40.8) \quad (.53) \quad (1.69) \\ & + 12.32D + 235S + 523W \\ & \quad (2.10) \quad (100) \quad (204) \\ & - 136A \\ & \quad (154)\end{aligned} \tag{7}$$

where

$\hat{C}$ = expected cost
N = number of widgets
B = average number of widgets in a batch
D = number of digits
S = summer dummy variable, where $S = 1$ for summer, 0 for other seasons
W = winter dummy variable, where $W = 1$ for winter, 0 for other seasons
A = autumn dummy variable, where $A = 1$ for autumn, 0 for other seasons
R^2 = .892 (the coefficient of multiple determination)

Standard error of estimate = 420.83, which is 5 per cent of the dependent variable, cost.

Number of observations = 156.

The numbers in parentheses beneath the coefficients are the standard errors of the coefficients. These results may be used for such purposes as price and output decisions, analysis of efficiency, and capital budgeting.

For price and output decisions, we would want to estimate the average marginal cost expected if an additional widget is produced. From the regression we see that the estimated average marginal cost, $\partial C/\partial N$ is 8.21, with the other factors affecting costs accounted for. The standard error of the coefficient, .53, allows us to assess a probability of .67 that the "true" marginal cost is between 7.68 and 8.74 ($8.21 \pm .53$) and .95 that it is between 7.15 and 9.27 (8.21 ± 1.06).[26]

The regression also can be used for flexible budgeting and analysis of performance. For example, assume that the following production is reported for a given week:

$W = 532$
$B = 20$
$D = 321$
S = summer = 1

Then we expect that, if this week is like an average of the experience for past weeks, total costs would be:

$$\begin{aligned}&110.3 + 8.21(532) - 7.83(20) \\ &+ 12.32(321) + 235(1) = 8511.14.\end{aligned}$$

The actual costs incurred can be compared to this expected amount. Of course, we do not expect the actual amount to equal the predicted amount, if only because we could not specify all of the cost-causing variables in the regression equation. However, we can calculate the probability that the actual cost is within some range around the expected cost. This range can be computed from the standard error of estimate and a rather complicated set of relationships that reflect uncertainty about the height and tilt of the regression plane. These calculations also reflect the difference between the production reported for a given week and the means of the production data from which the regression was computed. The greater the difference between given output and the mean output, the less confidence we have in the prediction of the regression equation. For this example, the adjusted standard error of estimate for the values of the independent variables given is 592.61. Thus, we assess a probability of .67 that the actual costs incurred will be between 7918.53

[26] The statements about probability are based on a Bayesian approach, with normality and diffuse prior distributions assumed.

and 9103.75 (8511.14±592.61) and probability .95 that they will be between 9696.36 and 7325.92 (8511.14±2·592.-61). With these figures, management can decide how unusual the actual production costs are in the light of past experience.

The regression results may be useful for capital budgeting, if the company is considering replacing the present widget assembly procedure with a new machine. While the cash flows expected from using the new machine must be estimated from engineering analyses, they are compared with the cash flows that would otherwise take place if the present machines were kept. These future expected flows may be estimated by "plugging" the expected output into the regression equation and calculating the expected costs. While these estimates may be statistically unreliable for data beyond the range of those used to calculate the regression, the estimates may still be the best that can be obtained.

Conclusion

The assertion has been made throughout this paper that regression analysis is not only a valuable tool but a method made available, inexpensive, and easy to use by computers. The reader may be inclined to accept all but the last point, having read through the list of technical and bookkeeping problems. Actually it is the ease of computation that the library computer programs afford which makes it necessary to stress precautions and care: It is all too easy to "crank out" numbers that seem useful but actually render the whole program, if not deceptive, worthless.

But when one considers that costs often are caused by many different factors whose effects are not obvious, one recognizes the great possibilities of regression analysis, limited as it may be. Nevertheless, it is necessary to remember that it is a tool, not a cure-all. The method must not be used in cost situations where there is not an ongoing stationary relationship between cost and the variables upon which cost depends. Where the desired conditions prevail, multiple regression can provide valuable information for solving necessary decision problems, information that can put "life" into the economic models that accountants are now embracing.

SENSITIVITY ANALYSIS IN DECISION MAKING

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Sensitivity analysis, a study to determine the responsiveness of the conclusions of an analysis to changes or errors in parameter values, can serve as an important aid in improving the basis for management decision making by facilitating a better understanding of risk. Sensitivity analysis not only is applicable to operating decisions but also can help establish guidelines for allocating scarce organizational resources to data collection and refinement activities. An illustration of the technique is presented.

Freedom from uncertainty is a luxury rarely enjoyed by the contemporary manager. In a society characterized by change, uncertainty is an established and accepted fact of life. Notwithstanding the difficulties, the decision maker is expected to attain satisfactory results as measured by the goals of the organization.

In the face of uncertainty, the most recurring questions are of the form, "What if...?"

1. What if our principal competitor successfully markets new product "X" six months before us? Three months? One month?
2. What if we were to defer our planned expansion program for one year? Six months?
3. What if the proposed merger were disallowed by the Justice Department?

The "what if" question may be viewed as an introduction to sensitivity analysis. In its mathematical sense, sensitivity analysis is a study to determine how possible changes or errors in parameter values affect model outputs. In its applied organizational setting, sensitivity analysis may be broadly defined as a study to determine the responsiveness of the conclusions of an analysis to changes or errors in parameter values used in the analysis.[1]

The principal objective of this article is to illustrate how sensitivity analysis can serve as an important aid in improving the basis for management decision making. The prime function of sensitivity analysis may be said to be to facilitate a better understanding of risk.[2] Specifically, sensitivity analysis tests the responsiveness of model results to possible variations in parameter

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[1] The terms "sensitivity analysis" and "simulation" are often used interchangeably. They are not, however, synonymous. Sensitivity analysis may be performed by analytical techniques, such as parametric linear programming, by experimental simulation approaches emphasizing numerous trials or iterations, or by a combination of these two approaches.

[2] Contemporary literature, by and large, still maintains F. H. Knight's distinction between risk and uncertainty [*Risk, Uncertainty and Profit,* (Boston: Houghton Mifflin Company, 1921)]. Risk is characterized by situations in which the outcome is not known with certainty, but where the probabilities of alternative outcomes are either known or can be estimated. Uncertainty refers to situations for which probabilities of outcomes cannot even be predicted in probabilistic terms. While this distinction may be a useful pedagogical device, there is serious doubt about its applicability to decision makers in an organizational context. Here the distinction is blurred by the fact that decision makers generally have some feelings about the probabilities of future events. Admittedly, these feelings range from a

values and thereby offers valuable information for appraising the relative risk among alternative courses of action. This technique is not only applicable to operating decisions,[3] but offers guidance for "information decisions" as well. That is, sensitivity analysis can provide guidelines for allocating organizational resources to data collection and data refinement activities. Applications of sensitivity analysis for both operating and information decisions will be presented.

Implicitly or explicitly, managers have actively employed sensitivity tests for appraising relative risk of alternative courses of action from the earliest stages of business development. What is new is the increasing use of the term "sensitivity analysis," the pervasiveness of its actual and potential applications with the advent of high-speed computers, and some recently developed mathematical techniques such as parametric linear programming[4] for testing sensitivity in complex, multivariable decision models. The benefits of subjecting models to sensitivity analysis are succinctly summarized by Arnoff and Netzorg:

> The use of an operations research model is especially important and advantageous in that it permits experimentation 'on paper,' without manipulation of the actual system. In using the model, one can assess the *sensitivity* (response) of the system to a wide variety of conditions—without requiring either the time, expense, or risks associated with experimenting with the system itself (if such experimentation would, in fact, be possible and meaningful). Hidden relationships can be brought to light and brought to bear upon decisions and control of activity.[5]

The importance of sensitivity analysis as an integral part of risk analysis varies with the degree of uncertainty. That is, the less certainty there is about values of model parameters, the more important it is to study the results of possible variations among parameter values.

degree of confidence bordering on certainty to ill-defined feelings approaching mysticism. The critical point remains that these feelings affect the judgments made by the decision maker. For this reason, the terms "uncertainty" and "risk" are here used interchangeably.

[3] Sensitivity analysis is particularly adaptable to the evaluation of risk for investment decisions. See, for example, Sidney W. Hess and Harry A. Quigley, "Analysis of Risk in Investments Using Monte Carlo Techniques," *Statistics and Numerical Methods in Chemical Engineering*, Chemical Engineering Symposium Series, LIX, No. 42 (New York: American Institute of Chemical Engineers, 1963), pp. 55–63; David B. Hertz, "Risk Analysis in Capital Investment," *Harvard Business Review* (January–February, 1964), 95–106; William C. House, Jr., "The Usefulness of Sensitivity Analysis in Capital Investment Decisions," *Management Accounting* (February, 1966), 22–29. Readers interested in applications of sensitivity analysis to other decision models may wish to review the following references: William Beranek, *Working Capital Management* (Belmont, Calif.: Wadsworth Publishing Company, Inc., 1966), Chap. 5. Beranek illustrates sensitivity analysis with an inventory-control model for working capital. A similar example for merchandise inventory can be found in *Techniques in Inventory Management*, N.A.A. Research Report No. 40, National Association of Accountants, 1964, pp. 41–46. For an example of the sensitivity of the lease-or-purchase decision to alternative loan interest rates, see Richard S. Bower, Frank C. Herrington, and J. Peter Williamson, "Lease Evaluation," *The Accounting Review* (April, 1966), 257–65. For an early article illustrating sensitivity for a plant-location problem, an optimum lot size ordering model, transportation-cost problem, and a capital-goods replacement problem, see Richard B. Maffei, "Simulation, Sensitivity, and Management Decision Rules," *The Journal of Business* (July, 1958), 177–86.

[4] Parametric linear programming is discussed in detail later in the article.

[5] E. Leonard Arnoff and M. J. Netzorg, "Operations Research—the Basics," *Management Services* (January–February, 1965), 46.

A general model of a problem or decision situation can be expressed as follows:[6]

$$V = f(X, Y)$$

where

V = the measure of the value of the decision that is made

X = the variables which are subject to control by the decision maker, i.e., the decision variables

Y = the factors, variable or constant, which affect performance but which are not subject to control by the decision maker within the scope of the problem as defined

f = the functional relationship between the decision variables and performance factors, and the dependent variable V

Consider the sensitivity of the value of a decision to changes in parameter estimates in the context of a linear programming model. The linear programming model is commonly referred to as an "optimizing model." This label can be misleading, for it optimizes if, and only if, one assumes that all relevant variables have been properly incorporated and that values of the coefficients are sufficiently accurate. The ordinary linear programming model is deterministic; that is, it assumes that model data are known with certainty. To enhance the usefulness of linear programming to the planner, the certainty assumption must in many cases be relaxed, for he is often faced with uncertainties regarding such factors as future demand, prices, technological change, and so forth. Stochastic linear programming models in which either coefficients of the objective function, technological coefficients, or coefficients of the requirements vector are treated as random variables have been employed under conditions of risk.[7] Due to the computational burdens often associated with stochastic programming problems, applications to date have been limited.

Sensitivity analysis is another possible approach to risk evaluation when values of coefficients are subject to variation.

Actually, such coefficients are derived from analysis of data and usually represent *average* values or *best-estimate* values. Accordingly, it is most important to analyze the sensitivity of the solution to variations in these coefficients or in the estimates of these coefficients. Stated still another way, one seeks to determine the ranges of variation of the coefficients over which the solution will remain optimal. Sensitivity studies of this sort are known as *parametric linear programming*.[8]

The stability of the optimal solution to changes in coefficients has important managerial implications. For example, in a given situation a modest variation in a coefficient may result in a new optimal solution with a significantly

[6] Russell L. Ackoff, *Scientific Method: Optimizing Applied Research Decisions* (New York: John Wiley & Sons, Inc., 1962), p. 111.

[7] See G. Hadley, *Nonlinear and Dynamic Programming* (Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1964), Chap. 5; George B. Dantzig., *Linear Programming and Extensions* (Princeton, N. J.: Princeton University Press, 1963), Chap. 25; A. Charnes and W. W. Cooper, "Chance-Constrained Programming," *Management Science* (October, 1959), 73–79.

[8] E. Leonard Arnoff and S. Sankar Sengupta, "Mathematical Programming," in ed. Russell L. Ackoff, *Progress in Operations Research,* Vol. I (New York: John Wiley & Sons, Inc., 1961), p. 175.

lower maximum value for the objective function. On the other hand, a relatively large variation in another coefficient may result in little or no difference in the value of the maximum.

Case Study of an Operating Decision

To illustrate a sensitivity analysis for a linear programming solution, a case study is presented. Assume that during the recent surge of demand for color television sets a manufacturing company was considering how best to utilize its production facilities to maximize profits. The company produces three styles of black-and-white sets (standard, deluxe, and super) and a color set. The company confidently believes it can sell as many sets as it can produce. Each set goes through the plant's three departments — subassembly, assembly, and testing. The number of man-hours of labor required in each department is as follows:

	Standard	*Deluxe*	*Super*	*Color*
Subassembly	12	15	15	25
Assembly	10	12	13	20
Testing	0.5	0.6	0.6	2.0

The capacity of the plant allows no more than 3,500, 3,000, and 240 daily man-hours in the subassembly, assembly, and testing departments, respectively. Due to existing contractual agreements at least ten standard and ten deluxe models must be produced daily. The profit contribution (revenue minus variable costs) from the sale of each set is as follows:

	Standard	*Deluxe*	*Super*	*Color*
Profit contribution	$25	$30	$40	$100

The above can be expressed in conventional linear programming format as follows:

Maximize:

$$Z = 25x_1 + 30x_2 + 40x_3 + 100x_4$$

subject to:

$$12x_1 + 15x_2 + 15x_3 + 25x_4 \leqq 3500$$
$$10x_1 + 12x_2 + 13x_3 + 20x_4 \leqq 3000$$
$$0.5x_1 + 0.6x_2 + 0.6x_3 + 2x_4 \leqq 240$$
$$x_1 \geqq 10$$
$$x_2 \geqq 10$$
$$x_3, \quad x_4 \geqq 0$$

With the aid of a FORTRAN program for simplex linear programming, we find the optimum daily production schedule to be as follows:

x_1 — Standard — 10 units
x_2 — Deluxe — 10
x_3 — Super — 49
x_4 — Color — 99

This schedule yields an optimal profit of $12,410.

The confidence of the decision maker in the optimal schedule is necessarily related to the confidence he has in the values initially recorded in the model. Variations within the model may be classified as follows:

1. Variations in objective function coefficients
2. Variations in technological coefficients
3. Variations in requirements vector coefficients
4. Addition or deletion of constraints
5. Addition or deletion of variables

Let us consider each of these variations to show how valuable management information can be derived from sensitivity studies. For each type of variation, examples of relevant analyses based on the television set product-mix problem are presented.

Variations in Objective Function Coefficients[9]

How far in each direction can the unit profit contributions for standard, deluxe, super, and color models vary without causing any change in the present optimal solution?

Profit contribution per unit for each of the four set styles is a function of their average or best-estimate values for selling price, cost of materials, direct labor, and other variable costs associated with their respective production. Variability in the value of these factors may or may not affect the optimum schedule and profits, but it is important that the decision maker have this information if parameter variability can in fact be expected. This information may serve as a basis for departing from the initial optimum schedule, but in any case should increase the confidence of the decision maker in whatever optimum schedule is ultimately used.

For the above problem, the table on this page shows the indifference ranges for objective function coefficients.

On balance the optimal schedule appears to be relatively insensitive to variations in objective function coefficients. For example, profit contribution for color sets (x_4) may vary from \$66.67 to \$133.33 per set without affecting the optimal schedule. For standard (x_1) and deluxe (x_2) sets the lower coefficient limit is represented by $-\infty$. This is so since the presence of ten units of each style in the optimal schedule is conditioned solely by contractual agreements for this amount reflected in the model as constraints, i.e., $x_1 \geq 10$ and $x_2 \geq 10$. From a managerial standpoint the lower limit of the objective function coefficient would presumably have to be greater than zero, since acceptance of contracts for less not only would incur opportunity losses but would decrease profits in the absolute sense as well.

Variable	*Style*	*Original Coefficient*	*Lower Coefficient Limit*	*Upper Coefficient Limit*
x_1	Standard	25	$-\infty$	32.67
x_2	Deluxe	30	$-\infty$	40.00
x_3	Super	40	30	60.00
x_4	Color	100	66.67	133.33

Next, what would be the optimum schedule and profit if the supplier should increase the price of color cathode-ray picture tubes by \$35 per units?

From the preceding analysis we have observed that the lower limit for the objective function coefficient for color sets (x_4) is \$66.67. The possible \$35 increase in cost would reduce the unit profit contribution for color sets from \$100 to \$65. Since the resulting profit

[9] The indifference ranges for objective function coefficients and requirements vector coefficients are an output of the computer program. All other inquiries in this section are solved by varying the input data and reworking the problem. I would like to express grateful acknowledgement to my colleague, Professor Joseph L. Balintfy, who developed the "FORTRAN Program for Simplex Linear Programming" (SIMUPF) used to solve the linear programming problems in this paper. For most of the examples to follow, sensitivity is studied on a *ceteris paribus* basis; i.e., one parameter value is varied, while all others are held constant. This is done in the interest of keeping the illustrations relatively simple. The analyst may vary any number of parameter values to study relevant sensitivity patterns.

contribution is outside the indifference range, the manager may well be interested in an alternate optimum schedule. A comparison between the original and adjusted optimal schedule and contribution profit follows:

		Optimal Schedule (Units)		
Variable	*Style*	*Original*	*Adjusted*	*Difference*
x_1	Standard	10	10	
x_2	Deluxe	10	10	
x_3	Super	49	196	+147
x_4	Color	99	11	− 88
Maximum contribution profit		$12,410	$9,105	−$3,305

There are significant changes in the new schedule for super (x_3) and color (x_4) sets. This is a particularly interesting result, since the lower limit of the objective function coefficient was breached by only $1.67, i.e., lower limit of $66.67 less adjusted profit contribution for color (x_4) sets of $65. It should be noted that the manager may find it appropriate to add an upper-bounded constraint for super (x_3) sets if demand is projected to be less than 196 units.

How sensitive is the optimal schedule and contribution profit to alternative pricing patterns for the four set styles? Where the first two questions in this section involve variations in parameter values which, by and large, are not subject to control by the decision maker, this question involves variations in a decision variable, since management is presumably in a position to establish prices.

A new manufacturer of color cathode-ray picture tubes has offered to meet one-half of the company's requirements at $5.00 per unit less than the price charged by the current supplier.

This question serves to illustrate the difference between optimal schedule sensitivity and optimal profit sensitivity. We determined earlier that the $100 profit contribution for color sets (x_4) may vary from $66.67 to $133.33 without affecting the optimal schedule. Consequently, in this situation the profit contribution would increase from $100 to $105 and no change in the optimal schedule results. There is, however, an increase of $250 in the optimal profit contribution. This increase results from obtaining a $5 per unit cost reduction for one-half of the 99 color sets scheduled under the optimal plan. The benefit of a $250 increase in profit must now be weighed against the uncertainties and possibly unfavorable consequences of dealing with a new and untested supplier.

Variations in Technological Coefficients

1. The technological coefficients are based upon values taken from the company's standard cost system. Due to personnel problems in the subassembly department and possibly to a relatively high rate of turnover, an average unfavorable labor efficiency variance of 10 per cent is a distinct possibility. Does this affect the optimal schedule and profit? A labor efficiency variance also affects the objective function coefficients. For example, at a $3.00 per hour labor rate in the department a 10 per cent increase in labor time would increase cost by $3.60 per unit for the standard (x_1) sets, i.e., 1.2 increased hours at $3.00 per hour. The model

with adjusted coefficients is now expressed as:

Maximize:

$$Z = 21.4x_1 + 25.5x_2 + 36.5x_3 + 92.5x_4$$

subject to:

$$13.2x_1 + 16.5x_2 + 16.5x_3 + 27.5x_4 \leqq 3500$$

$$10x_1 + 12x_2 + 13x_3 + 20x_4 \leqq 3000$$

$$0.5x_1 + 0.6x_2 + 0.6x_3 + 2x_4 \leqq 240$$

$$x_1 \geqq 10$$

$$x_2 \geqq 10$$

$$x_3, x_4 \geqq 0$$

The solution to this revised problem indicates that the optimal schedule and profits are sensitive to labor inefficiencies in the subassembly department. This result is not altogether surprising, since subassembly as well as testing capacities are fully utilized in the original optimal schedule while there are 147 man-hours of slack in the assembly department. A comparison between the original and adjusted optimal schedule and contribution profit follows:

		Optimal Schedule (Units)		
Variable	*Style*	*Original*	*Adjusted*	*Difference*
x_1	Standard	10	10	
x_2	Deluxe	10	10	
x_3	Super	49	6	−43
x_4	Color	99	112	+13
Maximum contribution profit		$12,410	$11,118	−$1,292

2. From the original optimal schedule, management noted that subassembly and testing represented the limiting resources. In view of this and the low rework rate, active consideration is being given to reducing the testing time on color sets from an average of two hours to 1½ hours per unit. While this policy change would increase maximum profit from $12,410 to a new optimal of $13,450, super ($x_3$) sets would be eliminated from the schedule. This development will be examined more fully in connection with discussion involving addition of constraints.

Variations in Requirements Vector Coefficients

1. The requirements vector coefficients are 3,500, 3,000, and 240 daily man-hours in the subassembly, assembly, and testing departments, respectively. How far can available labor capacity for each of the three departments vary before a change is generated in the optimal solution?

The average or best-estimate of labor-hour capacity for the subassembly and testing departments must be exact for the optimal solution to be stable. Profits would decrease if actual capacities were less than estimated capacities, since estimated capacities were fully utilized in the solution. The dual evaluators, or shadow prices, for subassembly and testing capacity are $1.33 and $33.33, respectively. These shadow prices represent the decrease in profit associated with making one less hour of these resources available. Conversely, these shadow prices also represent the incremental profit from increasing these

two resources by one hour, respectively.

As indicated earlier, there are 147 man-hours of unused or slack time in the assembly department. Thus, the 3,000 estimated man-hours may actually be as little as 2,853 hours (3,000 less 147), and the solution would remain unchanged. Similarly, additional assembly capacity would not benefit profit, since the resources of the other two departments remain the limiting resources.

2. Since subassembly as well as testing facilities are fully utilized in the original optimal schedule, management has reasoned that with a minimum of plant rearrangement about 100 hours of man-hour capacity can be transferred beneficially from the assembly department to the subassembly department. They wish to know the optimal schedule and profit if such a transfer is accomplished, and testing time for color (x_4) sets is two hours? 1½ hours?

If testing time for color (x_4) sets is reduced to 1½ hours, then once again super (x_3) sets are excluded from the optimal solution—an unacceptable condition to management. If testing time were to remain at two hours per color set, then the rearrangement of subassembly and assembly capacities would increase maximum daily profit contribution from $12,410 to $12,450. This benefit must then be weighed against the cost associated with plant rearrangement.

Addition of New Constraints

Because of the brisk demand for color sets, the company's supplier may well limit shipments of color cathode-ray picture tubes to ninety per day. How costly would this be and what is the new optimum schedule?

With the addition of this constraint, maximum profit contribution is reduced from $12,410 to $12,150, a reduction of $260. The optimum schedule again calls for the production of ten units each of standard (x_1) and deluxe (x_2) styles. Sixty-five super (x_3) sets are now to be produced daily, while the upper limit of ninety color (x_4) sets is called for under the new optimum schedule.

Before the recent popularity of color (x_4) sets, the super (x_3) set was the company's most popular and profitable style. Indeed, the company's growing reputation for quality has been developed largely through the marketing of the super set. In light of this, management believes that despite active consumer demand for the more profitable color sets, demand for super sets should continue to be met to a reasonable extent. The original optimal schedule calls for a daily production rate of 49 super sets. Management estimates current demand to be approximately 100 sets per day. Management wishes to know the costs of deviating from the previously established optimal solution for satisfying various percentages of demand for super sets. For example, if we wish to test the effect of meeting 75 per cent of the demand, the following constraint would be added to the original model:

$$x_3 \geqq 75$$

Addition or Deletion of Variables

The company's sales volume for the two lower priced sets, the standard (x_1) and the deluxe (x_2), has been disappointing despite concentrated marketing effort. In order to be able to offer a "full line," the company must market a lower priced set. Management believes that either the standard or the de luxe style can be gradually discontinued without seriously jeopardizing the "full line" image. What impact would each of these two possible changes have upon the optimum schedule and profit?

The foregoing questions represent but a limited sample of potentially relevant inquiries once initial model results have been established. The important points are that a wealth of information can be gleaned from sensitivity studies and that the basis for decision making can be significantly improved with the use of this technique.

Sensitivity Analysis for Information Decisions

Sensitivity analysis can provide systematic guidelines for allocating organizational resources to data collection and refinement activities.[10] Management science techniques are not only applicable to operating decisions, but offer guidance for decisions concerning the information system as well. After the analyst has constructed a model and tested it with initial parameters, he is faced with a decision problem. He may choose to collect additional data, refine initial parameters, alter the model, or use the model results as a basis for recommending action to management. On the significance of this decision, William T. Morris comments:

> The nature of management science is such that sooner or later it has to recommend some action other than making more observations. Usually this comes sooner rather than later. Eventually it will suggest that action be taken consistent with either acceptance or rejection of the hypothesis. It will recommend management 'act as if' the hypothesis were true or 'as if' it were false. *Indeed, the fundamental question in management science may well be when to stop collecting data and developing the model, and when to produce a recommendation for action.*[11]

A theory of the cost and value of information for "information decisions" is critically needed. In an increasingly technological society, information costs are ascending to previously unimagined heights. Further, impressive advances in electronic data processing signal an even more staggering amount of information potential. In the past, the emphasis has been on whether information required for decision making could be developed. With our growing capacity to generate data, the emphasis now appears to be shifting to the question of to what extent this capacity can be utilized beneficially. This question is the fundamental concern of those interested in information economics.

A sound economic theory of information requires an understanding of the determinants of both cost and value of alternative information configurations. Accuracy, reliability, and timeliness represent principal factors affecting both cost and value of information. The cost of increased accuracy, reliability, and timeliness can be approximated at various stages of processing. Value, on the other hand, must ultimately be related to benefits resulting from management action. Consequently, the analyst is faced with the recognition

[10] "The term 'data' is used here to represent messages that can be available to the individual but which have not as yet been evaluated for their worth in a specific situation. All communications in a firm may be considered as some form of data processing. 'Information' is used here as the label for *evaluated data* in a specific situation. When the individual singles out one of his problems and finds among his data materials that help him solve the problem, he is converting or isolating information from data. Note that a given message may remain constant in content and yet, under this approach, change from data to information when it is put to use in making a decision." [Adrian M. McDonough, *Information Economics and Management Systems* (New York: McGraw-Hill Book Company, 1963), pp. 71–72.] Given the foregoing definitions, were see that data collection and refinement activities can be evaluated solely in terms of the resulting information. This explains the choice of the term "information economics" rather than "data economics."

[11] William T. Morris, *Management Science in Action* (Homewood, Ill.: Richard D. Irwin, Inc., 1963), p. 113.

that while the collection and refinement of incremental data are costly, they may serve to improve recommendations for action. In perhaps most cases, the analyst has little basis for projecting whether the additional information is worth its cost. There will be numerous instances in which the additional information will not be worth the incremental costs. Indeed, in some cases it may not even be worthwhile to obtain initial information to determine whether developing the main information is economically sound. The gross decision rule, which suggests that data collection and refinement be continued until marginal costs exceed marginal benefits to the decision maker, furnishes little practical guidance.

The limited help offered by the deterministic marginal cost and revenue decision rule is attributable to the fact that oftentimes little is known about the characteristics of the information not yet developed. Statistical decision theory, a methodology for choosing a reasonable course of action under uncertainty, appears to offer more promising results in the area of information decisions. The basic inputs required for a statistical decision theory model for information decisions are neatly summarized by Morris:

> To apply this principle quantitatively it is necessary to be able to enumerate the possible outcomes of future data collection efforts and, further, to compute the probabilities of these outcomes. In addition, it must be possible to indicate just how the information will quantitatively change the decision maker's view of his choice.[12]

These requirements are not easily dismissed. They are essential to the information decision model but, unfortunately, often difficult to realize. An illustration will serve to demonstrate the importance of being able to enumerate possible outcomes of data collection efforts and to assign probabilities with a reasonable degree of confidence.

Grayson, in a particularly lucid exposition, demonstrates the application of decision theory to drilling decisions by oil and gas operators and also to the decision problem of whether to purchase additional information before making a final drilling decision.[13] Let us briefly outline the procedure.

The decision maker is confronted with the necessity of choosing between two acts: "drill" or "don't drill." The decision rule is to choose the act with the highest expected monetary value (EMV).[14] The EMV of an act is calculated by multiplying the monetary consequences of possible outcomes by the probability of occurrence associated with each outcome and then adding the resulting values for each outcome. For example, the EMV of $34,000 for the act "drill" is calculated as follows:

Possible Outcomes	*Profit or (Loss)*	*Probability*	*EMV*
Dry hole	($50,000)	.7	($35,000)
200,000 barrels	130,000	.2	26,000
500,000 barrels	430,000	.1	43,000
Expected Monetary Value			$34,000

[12] William T. Morris, *The Analysis of Management Decisions,* rev. ed. (Homewood, Ill.: Richard D. Irwin, Inc., 1964), p. 483. See also Norton M. Bedford and Mohamed Onsi, "Measuring the Value of Information —An Information Theory Approach," *Management Services* (January–February, 1966), 15–22.

[13] The discussion to follow is based upon the illustrations presented by C. Jackson Grayson, Jr., in *Decisions Under Uncertainty: Drilling Decisions by Oil and Gas Operators* (Cambridge, Mass.: Harvard Business School, Division of Research, 1960), Chap. 11.

[14] EMV decision rule is used by Grayson as a substitute for expected utility value solely to simplify the illustration.

The above probabilities are the geologists' personal or subjective estimates based upon presently available information. If a decision were to be made now, the act "drill" with an EMV of $34,000 would be favored over the act "don't drill" which has an EMV of $0. But the decision maker has the choice of either making the final decision with available information or obtaining additional information before making it. The decision maker must, of course, recognize that additional information is neither free nor perfectly predictable as to outcomes. In sum, the information decision is of much the same nature as the "drill—don't drill" operating decision.

Assume that the additional information under consideration is seismic and will cost $10,000. Seismograph information will lead to one of six interpretations. Using past frequencies as a guide, the decision maker is willing to stipulate the probability of each outcome (dry hole, 200,000 barrels, 500,000 barrels), conditional on obtaining a particular seismic result. An illustrative table from Grayson follows.[15]

All of the above outcome probabilities are *conditional* upon given seismic results. Next, consideration must be given to the unconditional probability of obtaining each of the six possible seismic results. Once again, historical data is used as a basis for projecting these probabilities. At this point, all data required to make the decision of whether to purchase seismic information are available.

Earlier we stated that the EMV of the act "drill" without obtaining additional information is $34,000. Consequently, the net EMV (after deducting the $10,000 cost of seismic information) of the act "buy seismic" must be greater than $34,000 for it to be considered favorably. The net EMV of the act "buy seismic" is calculated as follows:

1. Calculate the EMV for each of the six possible seismic results. This is done by multiplying the monetary consequences of each outcome (dry hole, 200,000 barrels, 500,000 barrels) by the probabilities conditional on obtaining each particular seismic result, and adding the resulting values for each outcome.
2. Multiply each of the six EMV's (from

Table of Conditional Probabilities, Given Seismic Results

	Dry Hole	*200,000 Barrels*	*500,000 Barrels*	*Total*
Seismic Result: Good				
Structure closed	.30	.50	.20	1.0
Structure not closed	.75	.15	.10	1.0
No structure	.86	.07	.07	1.0
Seismic Result: Fair				
Structure closed	.30	.60	.10	1.0
Structure not closed	.90	.10	0	1.0
No structure	.80	.20	0	1.0

[15] C. Jackson Grayson, Jr., *Decisions Under Uncertainty: Drilling Decisions by Oil and Gas Operators* (Cambridge, Mass.: Harvard Business School, Division of Research, 1960), p. 330. See A. Charnes and W. W. Cooper, *Management Models and Industrial Applications of Linear Programming* (New York: John Wiley & Sons, Inc., 1961), Vol. II, Chap. 19, for relationship of game theory to linear programming.

Step 1) by the unconditional probability of obtaining each of the six seismic results. Add the resulting six EMV's for seismic results to obtain the EMV of the act "buy seismic."
3. Subtract the $10,000 cost of seismic information from EMV of the act "buy seismic" to obtain the net EMV.

In the Grayson illustration the net EMV of the act "buy seismic" is $46,400. Thus, following the predetermined decision rule, the decision maker would presumably buy seismic information. Thereafter, a drilling decision can be made on the basis of the EMV of the resulting seismic interpretation.

Let us now consider the conditions under which a statistical decision theory approach, as described above, can be employed for making information decisions. The Grayson model requires the following inputs:

A. To obtain EMV of the decision "don't buy seismic":
 1. Monetary consequences of possible outcomes
 2. Probabilities associated with each outcome
B. To obtain net EMV of the decision "buy seismic":
 1. Cost of additional information
 2. Possible results of further data collection efforts
 3. Probabilities associated with each data result
 4. Monetary consequences of possible outcomes
 5. Conditional probabilities of outcomes, given each possible result of data collection

Let us postulate that inputs A-1 and A-2 above can be developed, although with varying degrees of confidence. Let us further assume that input B-1 can be reasonably approximated. For many important business decisions, there is serious question regarding the capacity of analysts and decision makers to develop reasonable parameters for inputs B-2 through B-5. This again is the nagging problem of situations in which the analyst has little basis for projecting the value of incremental information. Unfortunately, in too many situations "seismic-type information" is not easily developed. By "seismic-type information" is meant information characterized by two principal data-gathering attributes:

1. There are a finite number of data-gathering results. They can be enumerated in advance of actual data gathering.
2. The probability of obtaining each data-gathering result can be specified with a reasonable degree of confidence and, further, can be related quantitatively to the expected value of the decision. The foregoing analysis of the decision theory approach to information economics suggests that it appears to offer an invaluable guide when "seismic-type information" is available. In the absence of "seismic-type information," other strategies for making information decisions should be explored.

Simon offers the following view of sensitivity analysis:

> Because management scientists became keenly aware of the imperfections of the data with which they worked, they early developed an interest in "sensitivity analysis." Sensitivity analysis is aimed at estimating the costs of making decisions with bad data and, correlatively, at estimating the value of procedures to improve the data.[16]

Simon emphasizes the "risk analysis" and "information economics" applications of sensitivity analysis. This is not surprising, since these two applications of sensitivity analysis can be performed

[16] Herbert A. Simon, "New Developments in the Theory of the Firm," Papers and Proceedings of the Seventy-fourth Annual Meeting of the American Economic Association, New York, December 27–29, 1961, *American Economic Review* (May, 1962), 4.

simultaneously. We will use the linear programming model presented earlier to illustrate the validity of the foregoing proposition. Also, we wish to show how decision theory and sensitivity analysis are each relevant to information decisions.

Let us first compare the basic questions asked in the decision theory and sensitivity analysis approaches to information decisions.

1. *Decision theory.* Will the expected value (utility) of additional information be worth the cost (effort) of obtaining it?
2. *Sensitivity analysis.* How sensitive is the value of the decision to possible parameter variations?

Under the sensitivity analysis approach if the value of the decision is insensitive to estimated parameter variations, then the decision to purchase no additional information can be made without introducing a statistical decision model. If the decision is sensitive, then some judgment must still be made regarding the wisdom of initiating further data collection and refinement. It is at this point that a statistical decision model may be applied beneficially, as shall be illustrated later. To summarize, there are two important advantages for the sensitivity analysis approach to information decisions:

1. A sensitivity analysis underlying an information decision can be performed simultaneously with the sensitivity analysis for the evaluation of risk.
2. A sensitivity analysis which discloses decision insensitivity to estimated parameter variations precludes the necessity of introducing more costly, time consuming statistical decision models into the analysis.

Case Study of an Information Decision

Let us now return to the linear-programming model used to solve the television product-mix problem. We shall now attempt to illustrate how sensitivity analysis and statistical decision can be used jointly for information decisions. In our earlier analysis, we noted that the lower limit for the objective function coefficient for color sets (x_4) is \$66.67. Management is concerned over a possible \$35 increase in the price of color cathode-ray picture tubes. Such an increase would decrease the profit coefficient for color sets from \$100 to \$65. Since \$65 is outside the indifference range, we re-solved the problem and obtained the results shown below.

Management is quite concerned over the significant changes in profits and production schedules under the revised optimal solution. Management believes that radical and numerous changes in production mix can be expensive both in terms of average employee productivity and set up costs. For this reason, management would prefer to maintain

		Optimal Schedule (Units)		
Variable	*Style*	*Original*	*Revised*	*Difference*
x_1	Standard	10	10	
x_2	Deluxe	10	10	
x_3	Super	49	196	+147
x_4	Color	99	11	− 88
Maximum contribution profit		\$12,410	\$9,105	−\$3,305

either the original or the revised production schedule for the forthcoming month. Management cannot expect to know the supplier's pricing decision until it becomes effective on the first day of next month. Customers require promised shipping dates. The production planning department requires advance notice of any major changes in production mix. Consequently, the production decision for next month must be made before the first of the month.

Management thus has two choices, to follow the original or the revised optimal schedule in the face of two possible outcomes, no price increase or a $35 price increase. The value of daily outcomes for each possible act or decision can be presented in a payoff table as follows:

	O_1	O_2
A_1	12,410	8,945
A_2	9,490	9,105

where

A_1 = the act "implement orginial optimal schedule"

A_2 = the act "implement revised optimal schedule"

O_1 = the outcome "no price increase"

O_2 = the outcome "$35 price increase"

The payoffs for A_1O_1 and A_2O_2 represent the initial and revised maximum profit contributions, respectively. The opportunity loss of using the revised schedule in the event of no price increase is $2,920, i.e., $12,410–$9,490. The opportunity loss associated with implementing the original schedule in the event the $35 price increase materializes is $160, i.e., $9,105–$8,945.

To convert the daily payoff table to a payoff table for the forthcoming month, all values are multiplied by 25, the number of planned production days:

	O_1	O_2
A_1	310,250	223,625
A_2	237,250	227,625

Based on presently available information, management assigns probabilities of .60 and .40 to O_1 and O_2, respectively. If management were willing to invest approximately $1,000 for researching this problem, it is believed that the odds are 9 to 1 that they will correctly predict the actual outcome. Should management invest in the research necessary to develop the additional information?

First, we will calculate the EMV[17] of the best decision with presently available information. This is done using the decision tree format in Figure 1 and yields an answer of $275,600.

We now calculate the EMV of the best decision, assuming that management decides to invest $1,000 to obtain additional information. As stated earlier, management believes that the addi-

[17] Just as in the Grayson model, the EMV decision rule is used instead of expected utility value, solely to keep the illustration simple. When utility is not linear, the EMV decision rule must be used with discretion.

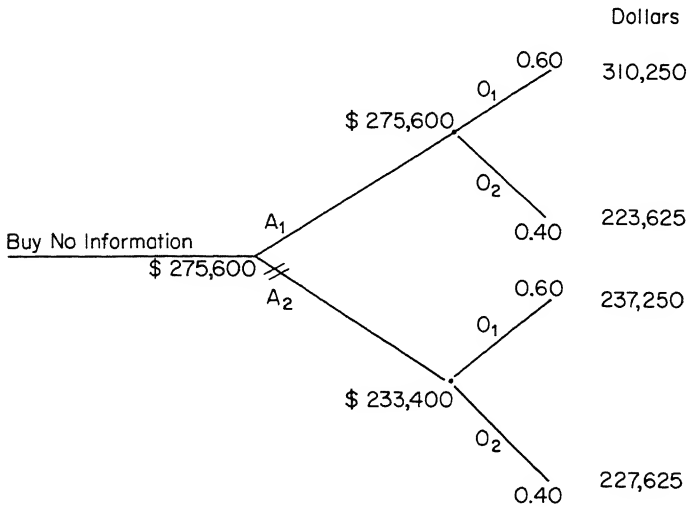


Figure 1

Decision tree diagram illustrating EMV of best decision with presently available information

tional research will lead to a correct prediction of an outcome 90 per cent of the time. The matrix presented below summarizes the relevant joint and marginal probabilities.

	O_1	O_2	Total
Say 1	.54	.04	.58
Say 2	.06	.36	.42
Total	.60	.40	1.00

where

Say 1 = the prediction "no price increase"

Say 2 = the prediction "$35 price increase"

O_1 = the outcome "no price increase"

O_2 = the outcome "$35 price increase"

We know that the prior expectations for O_1 and O_2 are .60 and .40, respectively. These figures are reflected as the column totals of the matrix. If O_1 can be expected with .60 probability and predictions are correct with .90 probability, then the joint probability of both events occurring simultaneously is .54, i.e., .60 × .90. This condition is reflected in element Say 1-O_1 of the matrix. Conversely, the joint probability of O_1 and an incorrect prediction of Say 2 is .06, i.e., .60 × .10. This is naturally reflected in element Say 2-O_1 of the matrix. A like procedure is followed to obtain the joint probabilities for the O_2 column. The new totals of the matrix reflect the marginal probabilities associated with Say 1 and Say 2. That is, Say 1 and Say 2 will occur with probabilities of .58 and .42, respectively.

From the data in the matrix the posterior probabilities for outcomes can easily be calculated. For example, given that Say 1 is predicted, what is the probability (P) that O_1 will occur?

By reference to the matrix we know that Say 1 will be predicted with probability .58 and that the joint probability of Say 1 $-$ O_1 is .54. Thus, we see that:

$$P(O_1|\text{Say } 1) = \frac{.54}{.58} = .931$$

We can further state that:

$$P(O_2|\text{Say } 1) = \frac{.04}{.58} = .069$$

$$P(O_1|\text{Say } 2) = \frac{.06}{.42} = .143$$

$$P(O_2|\text{Say } 2) = \frac{.36}{.42} = .857$$

We will again revert to the decision tree format to illustrate the calculation of the EMV of the best decision with additional information available. In Figure 2, working from right to left, we find the dollar payoffs or consequences for the various action-outcome combinations. These values are taken directly from the monthly payoff matrix presented on page 187. These payoffs are multiplied by the posterior probabilities to obtain EMV's for the outcomes. These EMV's, \$304,272, \$236,585, \$236,012, and \$229,001, can be found at the series of nodes one step back from the right endpoints. At this point a choice between A_1 and A_2 is made using the "maximize EMV decision rule." In each case, A_1 is chosen and the associated EMV recorded at the next node. The EMV of the best decision with the additional information is then calculated by: (1) multiplying the EMV of A_1 given Say 1 (\$304,272) by the probability that Say 1 will occur (.58); (2) multiplying the EMV of A_1 given Say 2 (\$236,012) by the probability that Say 2 will occur (.42); and (3) adding the results of the first two steps.

We note that the value of the decision with the additional information is \$275,600 and also that this is equal to the EMV of the decision without additional information. Why is this so? It is because the best act given Say 1 is A_1, and the best act given Say 2 is A_1. Consequently, the information that

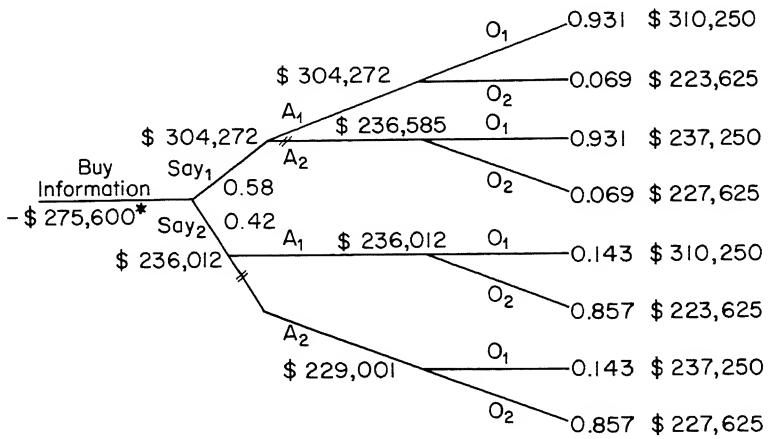


Figure 2

Decision tree diagram illustrating EMV of best decision with additional information

* Adjusted from \$275,603 for rounding errors.

management receives, whether it be Say 1 or Say 2, will not affect its choice. If this is the case, common sense dictates that the information is valueless. In sum, we have employed a statistical decision model and determined that the value of the decision in this problem is insensitive to incremental information which can correctly predict the actual outcome 90 per cent of the time.

Summary

1. In its applied organizational setting, sensitivity analysis may be broadly defined as a study to determine the responsiveness of the conclusions of an analysis to changes or errors in parameter values used in the analysis.
2. Sensitivity analysis tests the responsiveness of model results to possible changes in parameter values, and thereby offers valuable information for appraising the relative risk among alternative courses of action.
3. Sensitivity analysis can provide systematic guidelines for allocating scarce organizational resources to data collection and data refinement activities.
4. Under the sensitivity analysis approach, if the value of a decision is insensitive to estimated parameter variations, the decision to purchase no additional information can be made without introducing a statistical decision model.
5. If the value of a decision is sensitive to estimated parameter variations and the information decision is not obvious, a statistical decision model may be developed to guide the information decision.

Editorial Comment for Chapter 4

The readings in this chapter treat the problem of dealing with the uncertainty inherent in relevant planning and control variables. In the first two readings, forecasting with the use of statistical techniques is emphasized. Forecasting should be clearly distinguished from planning. The former is the process of arriving at deterministic or probabilistic predictions of values associated with future events. By contrast, planning is the process of establishing and changing, as required, guidelines and constraints for the behavior of the firm. Forecasts thus represent a key input into the planning process. When, for example, a forecast estimates that a firm will not achieve its stated goals in forthcoming periods, further planning is initiated to see whether revised strategies can alter events underlying the disappointing forecast.

Strassmann's article offers an interesting discussion that outlines how relevant information (forecasts of short-term customer demand) and a well-conceived organizational plan for its transmission can lead to an improved basis for decisions and, thereby, help lower costs. As Strassmann specifically illustrates, delays in a segmented information system can be significantly reduced by rearranging the flow of information. Note that reduction in information delay is accomplished largely by eliminating several organizational "filters"; for example, instead of forecasts being transmitted to the divisional production planning group for review and possible modification, they are relayed directly to decentralized production points. Strassman does not discuss the organizational consequence of changes in information flow, but, undoubtedly, in many cases, they represent an important consideration. If the distribution of relative power among organizational members is, as most observers would suspect, related to the acquisition of knowledge, then organizational relationships can be sensitive to alternative information flows. It is difficult and unwise to speculate about how specific information flow changes (including the timing of flows) are likely to affect a given firm without an in-depth understanding of that firm's internal and environmental systems. Nonetheless, for the Strassmann example, it seems safe to conjecture that the role of the production planning group, as it relates to other segments of the organization, will be affected by the recommended change in information flow.

The discussion of the appropriate level of aggregation for forecast raises some further organizational issues. Strassmann suggests that "subject to limitations of cost and availability of data, forecasting should take place at the lowest possible

level of detail within the shortest forecasting cycle available." He contends that information systems designers may be tempted to develop forecasts at higher levels of aggregation because management is not convinced of the need for more detailed information, and, further, the analyst may be concerned about the increased margin of forecasting error at lower levels of aggregation. Anthony's framework, discussed in the last chapter, provides some useful guidelines for considering the question of aggregation. For purposes of strategic planning and, perhaps to a lesser extent, management control, higher levels of aggregation and longer forecasting cycles would be useful. For purposes of operational control, when we are interested in efficient acquisition and use of resources for specific and detailed activities, lower levels of aggregation and relatively short forecasting cycles would, in all likelihood, be more relevant.

The relative advantages and disadvantages of short versus long information intervals have been summarized by one author as follows:

Advantages of Short Information Intervals

1. Short intervals decrease the amount of information which must be stored until the next production cycle, thus lowering the cost of information storage devices needed, such as computer disks, filing cabinets, etc.
2. Information appearing at frequent intervals makes possible early identification and correction of emergency conditions.
3. If information is not produced often enough, "bootleg" records will be kept by the recipients. It will be uncontrolled and inaccurate. Conversely, "bootlegging" is invariably a danger signal that the information system it duplicates is in some way inadequate.
4. Shorter information intervals mean fresher news which will more effectively draw the attention of those receiving it.

Advantages of Long Information Intervals

1. As already mentioned, longer intervals mean fewer information production cycles in the course of the year and thus lower total production setup costs and lower overall information expense.
2. Reports covering longer periods reduce the importance of unusual one-time or few-time events to their proper magnitude, while in short-interval reports such events can appear unduly serious. In short, reports produced less often permit easier recognition of trends.
3. Reports produced at longer intervals tend to be reviewed thoroughly. If a report appears too often, its recipient tends to collect and summarize it rather than read it, or to ignore it altogether.[1]

Once forecasts of demand for company products have been satisfactorily established, well-conceived projections of costs become essential to effective manage-

[1] Rudolph E. Hirsch, "The Value of Information," *Price Waterhouse Review,* XIII (Spring, 1968), 24–25.

ment planning and control. Direct estimating, industrial engineering studies, and statistical analysis of historical data all represent methods of predicting cost behavior. The Benston paper advocates a statistical approach to the cost measurement problem, rather than an informal, *ad hoc* approach. There is mounting evidence of increasing use of statistical cost analysis in industry and government. We must, however, view any analysis that relies heavily upon historical data in proper perspective. Specifically, historical data are relevant only insofar as they aid prediction. This proposition leads us to the ironic suggestion that the more dynamic an organization is, the more caution it must exercise in using statistical analysis. For it is precisely the firm that anticipates, or at least responds quickly to, environmental changes by introducing new production technologies, distribution methods, and organizational arrangements that finds historical data least useful.

The problem of choosing appropriate levels of aggregation exists for cost analysis, as it does for demand forecasting. Consider, for example, the case of a conglomerate that is growing primarily through acquisitions. If the means for conducting divisional business have not changed significantly over the past few years, then statistical analysis may prove useful at the divisional level. To depend upon such analysis for executive-level aggregation of the entire company, however, may well be misleading. Rapid growth via acquisition means that today the company is a far different economic entity than it was last year, and it may have little relationship to the company that existed two or more years ago. Statistical analysis in such a situation would mean extrapolating from data no longer representative of the scope of current and—more important—contemplated activities.

Some authors urge the use of simple linear regression to study cost behavior patterns; Benston, however, argues for the intelligent use of multiple regression analysis. The latter approach recognizes that there may be a number of other cost-causing factors besides output. The sensitivity of the dependent cost variable to the use of a multiple regression model as contrasted with a simple linear regression or nonstatistical estimate depends upon the unique situation for any given entity of interest. Even more important than the sensitivity of this variable is the sensitivity of management decisions to the different measurements that come about through application of alternative cost analyses models. The information economics guideline presented in Chapter 2 suggests that using a more complex model—in this case multiple regression—is warranted when the expected value of the resulting decision exceeds the expected value of the decision resulting from less complex models by a margin greater than the projected incremental costs associated with using the more complex model.

The value of multiple regression analysis must be assessed in light of the potentials for measurement error outlined by Benston and others.[2] The problem of multicollinearity conditions may, in many cases, be difficult to avoid, since factors affecting the dependent cost variable are frequently related to each other. The requirement that data taken from a firm's accounting system must often be reclassified to become acceptable inputs in the regression model further complicates

[2] See, for example, Robert E. Jensen, "A Multiple Regression Model for Cost Control—Assumptions and Limitations," *The Accounting Review,* XLII (April, 1967), 265–73.

the use of the model. When one carefully assesses the data requirements and potential measurement errors of a multiple regression model, Benston's contention that the ease and low cost of running the model on a computer may prove to be its undoing becomes all the more significant. On the other hand, a multiple regression model may allow management to gain new insights into factors whose effects upon the system are not apparent. Indeed, these insights may well provide a basis for altering a number of key decision variables to better achieve overall objectives. On balance, Benston's view that multiple regression can provide valuable information when desirable conditions prevail summarizes the situation well.

The Rappaport paper illustrates how sensitivity analysis may be used to gain a better understanding of risk and, thereby, improve the basis for decision making. The potential uses of sensitivity analysis in the development of information systems may be summarized as follows:

1. It guides the selection of an appropriate framework of analysis (i.e., model) underlying management decision making.
2. It tests the responsiveness of model results to changes in noncontrollable parameters and, thereby, offers valuable supplementary information for appraising the relative risk among alternative courses of action.
3. It tests the responsiveness of model results to changes in controllable parameters and, thereby, facilitates choice of "best available" management strategy.
4. It provides systematic guidelines for allocating scarce organizational resources to data collection and data refinement activities.
5. It represents a promising experimental technique to study systematically the effect of changes in information flows upon organization behavior.

The last application was not discussed in the Rappaport article and deserves a brief comment here. The effect of alternative information flows on organizational behavior has received scant attention. A study by Bonini, however, represents a promising framework for this type of research. Employing relevant theory from such disciplines as economics, accounting, organization theory, and behavioral science, Bonini constructed a computer simulation model of a hypothetical business firm. The study addresses itself in large part to what may be termed "behavioral sensitivity." A brief excerpt from Bonini's Preface clearly indicates this direction:

> The purpose of the model is to study the effects of certain informational, organizational, and environmental factors upon the decisions of a business firm. The analysis is accomplished by making alterations in the model (that is, changes in parts of the firm) and observing the effects of these alterations upon the firm's behavior. Thus, we formulate and test significant propositions about the behavior of business organizations in a laboratory-type experiment.[3]

To study the behavioral effects of alternative accounting practices, Bonini compared the effects of using the average cost method of inventory valuation with those of using the LIFO method. These were analyzed in terms of their

[3] Charles P. Bonini, *Simulation of Information and Decision Systems in the Firm* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1963).

influence on prices, costs, profits, and physical inventories, and a measure of the level of pressure within the firm. In brief, given the assumptions built into the model, Bonini concluded that the LIFO inventory method tends to increase the variability of profits from period to period in a highly variable environment and consequently promotes greater pressure, sales, and profits than the average cost inventory method. In a stable environment each of these two inventory methods should have the same effect. Whether these particular results can be empirically supported is a question to be answered by future research. The principal significance of the Bonini study lies in its demonstration of the power of the computer simulation technique for testing behavioral sensitivity in "total systems" fashion.

The value of a management information system is not absolute, instead it varies with people and organizations. This proposition, or more precisely this axiom, of information system design may well be overlooked occasionally because of the normal time pressures of industrial systems design. Nevertheless, such widely accepted management information system features as responsibility accounting and exception reporting are based either explicitly or implicitly upon certain behavioral assumptions. It is important to make these underlying assumptions explicit and to test their validity. By using models, such as the Bonini model, "real world" behavioral sensitivity studies will undoubtedly shed new light on the fascinating relationship between two of the most basic ingredients of organizational life—information and human behavior.

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5

Integrated Planning and Control Models: Selected Applications

SIMULATION IN FINANCIAL PLANNING

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Financial simulation aids the planning process by making it possible to generate a number of different plans quickly and economically. By forcing management to define and to quantify the relationships existing within the system and the interactions among the elements, it brings into clearer focus the hidden determinants of policy and practice. Uses of financial simulation models at the divisional and corporate levels are enumerated.

Simulation, the mathematical representation of a system in order to see how a change in one of its elements will affect the others, is—at least potentially—one of the most powerful tools of operations research. It is finding increasing use in the solution of military and production problems.

In the financial area its application is less well known. Simulations of economic and financial processes have been employed mainly as research and teaching aids. Little has been done to develop simulation techniques to improve precision and response in the financial plan-

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ning process within the corporate structure.

At Burroughs we have been experimenting with a simulation of the financial structure of the entire company. Our experience thus far has convinced us that this technique can provide management with an effective new planning tool.

This article, based on that experience, discusses the development of a financial simulation model structured around traditional accounting reporting practices. It emphasizes (1) the understanding of the business processes necessary to structure a useful model, (2) the model as a mirror of corporate policy, (3) the values and pitfalls in the use of a simulation model, and (4) certain methodological issues involved.

Simulation

Whenever the logical relations between the elements in a structure or a system can be quantified or expressed in measurable terms, a mathematical representation of these relationships can be formulated. The set of all these formal statements is then a model of the system. When we manipulate this model, the technique is called simulation. (This definition lacks the precision that the professional operations researcher would require, but it is adequate for the needs of the financial executive.)

As a tool applied to management problems, simulation is comparatively new. Its development and application are closely tied to the development and application of computer technology. It has been used to study complex problems in military strategy, traffic control, machine loading, and process control that do not lend themselves to solution by mathematical programming and other optimization techniques.

Because simulation has generally been applied to the nonfinancial aspects of business, many financial executives are as yet unaware of it. Yet simulation has proved to be a powerful tool when applied to the planning process.

In almost everything we do, the ultimate test of the adequacy of our decisions is the test of reality. But today business can seldom afford the luxury of testing the consequences of major decisions in the real world. Rather than determining the flight characteristics of a proposed missile by building and launching it, we now first simulate its performance on the basis of its design characteristics. In this way we can experiment without incurring the full cost of failure.

Similarly, in his role as planner, the executive is well aware of the magnitude of his investment decisions and the difficulty (sometimes the impossibility) of systematically evaluating all alternatives available to the company. He is also aware that he has at his disposal finite resources that have to be allocated among competing demands. Simulation techniques allow the businessman to examine the probable consequences of his decisions without the risk of real-life experimentation. They allow him to test the effects of his decisions on the whole corporation before these decisions are implemented.

Computers shorten the computational time period and thus permit repetitive use of the simulation model. This ability of the computer to compress the time needed to test the results of decisions makes experimentation much easier.

Management Science

Simulation is, of course, only one of a number of new mathematical techniques whose use has been facilitated by the availability of computers. During

the past decade we have seen a growing recognition by management of its need for newer and more sophisticated planning tools. Operations research and other techniques now frequently referred to as "management science" have emerged to help satisfy that need. They are contributing new skills to aid management in meeting the complexities of the decision-making process.

Not too long ago it was unusual to find a mathematician or statistician working in management. We had grown accustomed to his presence in the engineering department or the research laboratory, but we were surprised when we found him attacking such operational problems as production scheduling or inventory control. Now we even see him contributing to the financial planning function in such areas as capital budgeting, sales forecasting, and investment analysis. We see operations research and management science departments on the organization charts of many of our more progressive companies.

These professions, like all others, have developed their own characteristic approaches, methodology, tools, and techniques—decision theory, information theory, linear and dynamic programming, and network analysis, as well as simulation. These are now being applied to an increasing array of complex business problems.

Many of these techniques offer significant potential for use in financial planning. Simulation is particularly useful in this area because it can be applied to problems that are too complex and have too many variables to be reduced to optimization formulas. That is the reason we chose the simulation approach at Burroughs. It seemed to us the only means by which we could cope with the complexity of the financial planning process in the level of detail deemed essential while retaining the inherent flexibility needed to accommodate change.

Simulation Model

A financial simulation model can be defined as a formal statement of the relationships among the elements of a company's financial structure. Figure 1 illustrates what we term the "accounting dependencies" within the corporate structure of Burroughs. It has some similarity to our organizational pattern in that the elements on the chart represent units of management responsibility and managerial control, but they are not necessarily described in their organizational hierarchy. The figure reflects one aspect of our accounting practice —the way we consolidate. As such, it defines the framework of our financial model.

Two key points in our concept of financial simulation are illustrated by this figure. The first is the concept of modular construction. The total Burroughs model is actually a set of submodels, one for each of the management units shown. Specifically, we constructed individual models for each of these management units, expressing their output in accounting terms, and aggregated this output to produce the accounting consolidations indicated.

This design gives us the ability to identify and summarize the activities of each major corporate management unit. In addition, we can vary the form and level of detail between organizational units as a function of their inherent characteristics and their contribution to the planning process. Finally, the modular construction provides us with great model flexibility; it facilitates the introduction of worthwhile change to the program.

The second point we mean to illustrate in the figure is that there is a

logical sequence that must be followed. This sequence depends on the structure of the business. The output of certain models forms the input for others. The relationship thus created reflects the interplay between divisions. The ordering of the models is of prime importance.

If the model is to be an effective planning tool, it must explicitly reflect cause and effect both within the specific business process and between the business and the market in which it participates. In defining cause and effect in the model there are two considerations —the intermodel relationships and the intramodel detail. The former refers to "the explicit identification of the cause and effect factors that determine the relationship and, thus, the ordering between the submodels." The latter refers to "the level of detail essential in structuring one of the submodels per se." Let us discuss each of these factors.

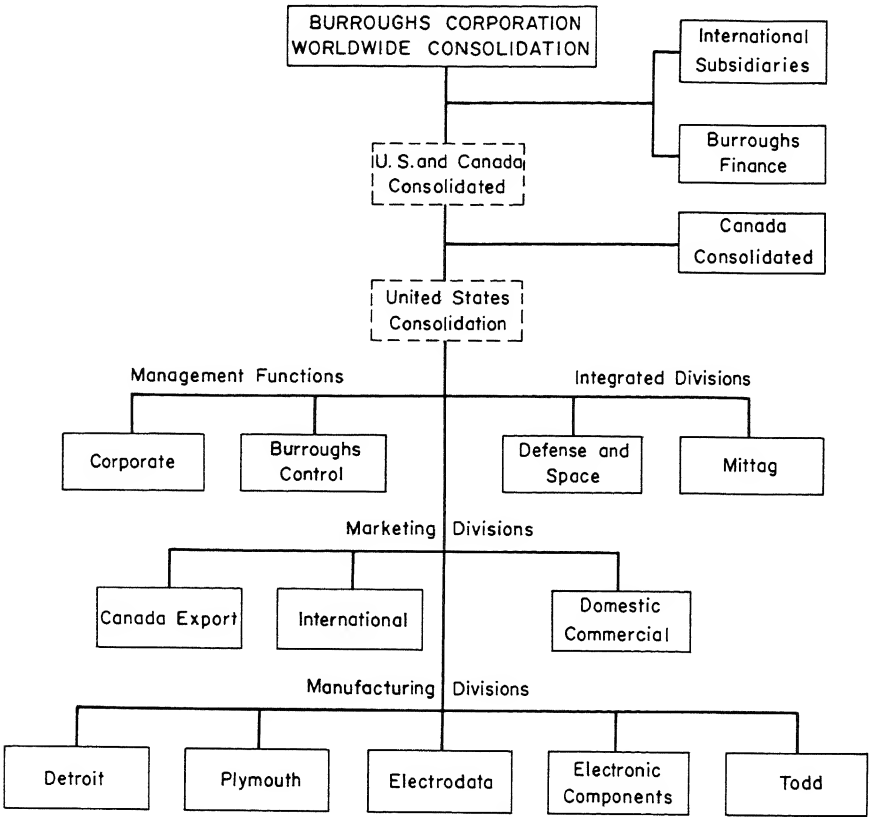


Figure 1

The "accounting dependencies" diagramed above define the framework of the model

Cause and Effect Relations

The importance of the intermodel relationship can be illustrated by dis-

cussing the relationship of demand to production in the total model complex. The marketing division models constitute the primary demand source within the total corporate model. The manufacturing divisions constitute the principal production source and capability, since we make what we sell. Because the marketing divisions are organized on a geographic basis and within their respective marketing areas handle the full product line, there is no direct interdivisional relationship influencing the ordering of the marketing models. On the other hand, the stimulus for the manufacturing division models is the output of the marketing models. Here—given policy as to desired inventory and capacity constraints—production levels and manufacturing expenses are determined. The cost penalties of constraints (and of constraints masquerading as policies) can also often be determined. This creates opportunity to assess the value of making changes. The models must specifically describe the form in which marketing demands are translated into production requirements both as a direct functional relationship, acknowledging the explicit interplay of company policy, and in terms of the time transformation represented in this relationship. The output of both the marketing models and the manufacturing models provides input to the "management" model where we determine financial capacity, taxes, etc.

A complex interaction exists among our various manufacturing facilities. While they are each primarily identified with a specific product, each acts as a subcontractor for assemblies, subassemblies, or parts to the other manufacturing facilities. Obviously, with this type of interaction any decisions made by the marketing organizations which affect demand rate will influence in varying degrees each of the manufacturing divisions, even though the decision might affect only one product in a wide product line. In order to create a useful planning tool, the development of the submodels must explicitly include a formal statement of this intermodel cause-effect relationship.

In the Burroughs Financial Simulation Model, the manufacturing interdivisional relation is accomplished by having the demand for all product lines carried to each manufacturing unit, even though they are primarily product organized, in order to acknowledge this interdivisional relationship. The model itself does not allocate total capacity among products so as to maximize production efficiency. In other words, the production sites for the various products have been predetermined for any simulation run. If capacity of a given producing unit will not satisfy the generated demand, both primary and secondary, we do not automatically adjust the demand. Rather we determine the imbalance and generate a report which states the deficiency in terms of demand lost or added capacity required to satisfy the demand input.

During the development of our model we found it expedient to view the cause-effect relationship we have just illustrated in a serial fashion. A better understanding is obtained by viewing the process as continuous rather than as sequential. The marketing demand interacts in the manufacturing sectors with capacity constraints and inventory policy to generate a production requirement. When this production requirement is accepted and met, goods are provided to marketing to satisfy the demand. Pricing and other marketing policies then determine revenue potential. This, in turn, affects the capital position and debt level of the firm. The capital position in turn defines the limits for the marketing

activity. The financial simulation model must reflect this feedback relationship explicitly or have some check and balance features incorporated to assure reasonable constraint.

Effects of Input Change

To illustrate the level of detail which we felt necessary to reflect in the simulation structure, we will trace the impact of a hypothetical change in input to our simulation model. Assume that we desire to evaluate the aggregate impact of a change in sales manpower in one of our marketing divisions. We have structured our demand forecast to be a function of the amount of direct sales manpower and a productivity function. In addition to evaluating the impact of the proposed manpower change through the relationship just identified, we explicitly evaluate the impact of the demand change on equipment and services revenue, cost of sales, and finished goods inventory. The impact of the demand change together with an inventory policy allows us to determine the resultant production requirement. This production requirement is an input in determining the in-process inventory. The determination of the production in-process activity provides the necessary stimulus for the determination of the subassembly and part manufacturing requirements, which in our model interact throughout the whole manufacturing sector. We must further relate this activity to its effect on variable, semivariable, and fixed costs of manufacturing, which collectively affect the burden absorption functions. Marketing expenses and commissions, freight and shipping costs, and interest expense will be affected. The change will affect the tax provision, after-tax profits, accounts receivable, and liabilities. It will affect the equity section, since dividends and retained earnings are both functions of net income. Indeed, it will be essential to evaluate the magnitude of funds required to carry out the suggested program which in itself has a feedback to marketing, where we began the illustration.

Process vs. Policy

Two categories of causative action are involved—one a function of the physical process, the other a matter of corporate policy. The establishment of an appropriate training pipeline to support a desired sales force represents a cause-effect relationship that is related to the "physical process" of the operation of the corporation; it also illustrates the introduction of a balancing and control mechanism on the marketing assumption. On the other hand, the inventory policy, which affects production requirements, is a reflection of corporate policy.

There is no pat answer to the choice of level of detail which must or should be represented within the simulation model. Nevertheless it is important that those specific considerations to which system performance is sensitive be separately identified and treated within the models. Certainly, all aspects of policy should be separately identified. The aggregation of details not only masks their individual impact but makes it difficult to use the results of the simulation; through lack of detail, precise responsibility for a change is unknown. Either condition makes it difficult to interpret an output of a simulation run for planning purposes. In creating a useful planning model, prudence cautions against presenting too much detail, but an excess of detail is preferable to overaggregation.

We have discussed the kinds of effects

on the corporate plan caused by introducing a single change of input to the marketing division submodel. We have mentioned the complex functional relationships that are affected throughout the system. It is important to reemphasize that the complexity of this relationship is not only a functional interaction but is also compounded by a time dimension; the nature of the relationship explicitly changes as time passes. For example, expenditures for research and development are not expected to produce revenue in the same period. These expenditures are investments in future revenue. We could term R&D a "lead" factor. It is important that we know, or make assumptions about and test the sensitivity to, the exact form of this time translation. On the other hand, administrative expenses may follow changes in revenue and, thus, in certain instances, could be classed as a "lag" function. In many situations the semivariable costs in the manufacturing sector show "asymmetric" properties relative to changes in production volume. That is, changes in semivariable costs may lead changes in production volume when they are increasing but lag changes in production volume in a down trend. These relationships must be derived. Their specific form is in most instances unique to a particular firm. It is essential that the relationships used in the model be adequately representative of the corporation's own processes.

A financial simulation model must not only reflect cause and effect within the firm and between the firm and its market, it must also be logically consistent with the financial practices of the firm and be a true representation of management policies and plans. These relationships are not simple, they are not God-given. To establish an adequate representation that will assure an effective planning tool requires a rigorous and continuous study program within the firm.

So far in our discussion we have used some language that may be peculiar to Burroughs' operations. It is not our intent, however, to emphasize our unique operating characteristics. The most important point is this: Since we have unique characteristics in our operations, our model must be structured to acknowledge and represent them. Furthermore, we are not unlike any other dynamic organization. The interactions within our corporate structure are complex. The relationships are varied. The importance of the planning process to our operations forced us to seek new tools. In order to use simulation techniques effectively, we had to establish a program which would result in a better understanding of our business in order that we could identify and quantify the essential cause-effect relationships and assure a realistic representation of management policies and their effect on the firm.

Uses of the Model

Because of the complexity of the interactions that take place within the firm, it is difficult, if not impossible, for a human to think through all of the ramifications in the systematic form demanded for proper planning. Without the assistance of the simulation technique, we would have an overwhelming computational task and a very nasty communications problem in trying to respond to today's demands for planning information. The simulation model lessens the communications problem through the definition and quantification of the relationships within the system. We cannot emphasize too strongly that you must be honest with yourself; you must learn about yourself and the way you do business; you must

explicitly define and quantify the relationships applicable to your operation and your business. Otherwise, a simulation model will produce uninteresting, irrelevant, or erroneous information.

Our experience has verified that financial simulation can add a new dimension to the planning process. Simulation provides flexibility by making it possible to generate a number of different plans quickly, easily, and cheaply. By forcing management to define and to quantify the relationships existing within the system and the interactions among its elements, it brings into clearer focus the hidden determinants of policy and practice. By making automatic the process of tracing the effects of decisions throughout the system, it solves the problems of communication that exist within any dynamic and diversified organization. By integration with management information systems, it provides the potential for the development of feedback control systems. The following are some examples of the uses we have made of our financial simulation model:

At the Division Level

1. To learn the combined influence of independent decisions
2. To improve decision-making ability:
 a. To enforce discipline through formal relationships
 b. To allow the testing of independent decisions
 c. To point out problem areas
 d. To point out some inconsistent areas in decision making
3. To allow divisions to make several test runs before preparing their detailed forecasts

At the Corporate Level

1. To learn the effect on the corporation of a proposed divisional plan
2. To evaluate divisional "profit plans" and study alternative plans with respect to:
 a. Growth objectives
 b. Asset management
 c. Profit maximization
 d. Cash flow
3. To evaluate corporate decision alternatives
4. To prepare long-range financial and debt management plans

Clearly, financial simulation increases the effectiveness of the financial analyst. The responsible analyst has, of course, always been aware of the interactions among elements in the system and has considered these in the development of his projections. At the same time, however, he has been hampered by the restrictions placed on him by computational limitations. He has had to ignore variables and relationships that he knew were important simply because they could not be considered with the time and manpower resources he had available. He has been curious about the effects of altering certain basic assumptions but has never been able to test more than a few alternatives.

Today, burdened by increasing demands from top management, faced with more complex systems to analyze, and operating within the complex organizational and communications structure of a diversified corporation, the financial analyst needs the assistance that the technique of simulation can give him. Through the use of simulation, he acquires the potential for doing his job the way he has always wanted to do it.

Do's and Don't's

Now that we have examined the concepts of a financial model and seen how financial simulation contributes to the planning process, it may be helpful to summarize what we have learned about setting up a simulation program and the steps that must be taken in its implementation.

Construction of a model is an expen-

sive, time-consuming process and requires the cooperation of middle and some lower management across the organization. Without the active interest and participation of top management, the project is doomed to failure from the start. This fact is of primary importance.

A second ingredient essential to the success of the project is the joint participation of the operations research or management science staff and the corporate financial analysis group in the development of the model. This interdisciplinary approach is necessary to provide a balance between simulation technique on the one hand and financial logic and knowledgeability on the other. In our case, the operations research man acted as the hub of the simulation team. At the same time, participation by financial analysis guaranteed that the operations research techniques were not applied in a vacuum but were kept within the bounds of logical and meaningful financial relationships.

A fine measure of success of a financial simulation program is its actual use by management in the planning process. If executives' participation has been enlisted in the development of the model, they will become knowledgeable concerning the nature and use of the approach. They will understand how the model works, how to use the model to simulate various policies and plans, and how to interpret its output. This understanding on the part of managers and their willingness to participate adds realism to the model and facilitates its acceptance as an official corporate planning tool.

In developing a model, it is necessary to examine a multitude of data. Sound research and financial logic are required in order to extract from the total information stream those data that reflect cause and effect. Initial efforts should be directed toward examining past research and making use of relationships previously developed and tested. Where previous research has not provided an adequate base for model design, a research program must be initiated. If historical data are inadequate or judged not to be indicative of the future, one is forced to depend upon estimated relationships. Here the judgment of the informed manager is of great value in developing the necessary estimates.

After this approach has created an initial model, the model should be tested with actual data to measure the reasonability of its results. It is then modified and retested in a process continued until a simulation close enough to reality is obtained. No generalized criteria can be provided. What we are in fact doing is engaging in a formal validation procedure to ensure that the model actually mirrors the corporate financial structure and that it truly reflects the effects of policies, plans, and actions.

A financial model must be dynamic in nature. It must be periodically reworked in order to improve the precision with which functional relationships are stated, to incorporate the organizational changes that occur in any dynamic organization, and to reflect changes in accounting practice which could lead either to changes in established relationships or changes in the accounting structure of the model.

A simulation model, like anything else in life, can always be improved. We can simulate, test, modify, and simulate again, until we get as close to reality as we wish. However, in expending this effort, we should try to strike a happy and acceptable balance between realism, on the one hand, and cost, time, and complexity of the model on the other.

In guarding against oversimulation, however, we should not go to the other extreme of oversimplification. For then the accuracy and the realism of the

model are destroyed, and the effort expended becomes a costly exercise in futility.

The Planning Problem

The effort is worthwhile, for corporate planning—in particular, long-range planning—is a complex and difficult task. It requires sophistication and know-how on the part of the corporate executive who must formulate the corporate policies and plans that determine the future course of his organization.

The planning function is, first of all, a complex process. The executive is seeking to identify the alternatives available and assess their relative worth. The identification of reasonable alternatives is in itself a time consuming task, requiring the executive to sift through and analyze volumes of information. The determination of the relative desirability of these alternatives is made more difficult because of the element of uncertainty about the future within which each has been cast.

Uncertainty and change must be acknowledged as paramount forces to be coped with in the planning process. The balance between the need to make decisions and take action and the need for flexibility to permit adaptation to change remains a matter of judgment.

Changes are not only external. The organization, through expansion and diversification, may become more complicated as well. The economic environment, the acceptance of the company's product in the market place, and the company's cost of doing business are all affected in subtle but powerful ways by the complex interactions taking place between the enterprise on the one hand and government, labor, competition, and consumer demand on the other.

In addition to being complex, the planning process is a difficult one, increasingly so because of the shrinkage of time allowed the executive for response. As he attempts to cope with the complexities of his environment, the executive finds that his traditional patterns of decision making are breaking down in the face of ever increasing demands for faster reaction times. He recognizes the need for new planning tools to assist him in his planning role.

Traditionally, management has relied upon the financial segment of the organization for counsel in formulating plans. All activities have cost consequences. Hence, regardless of who else takes part in planning, the financial staff is an essential participant.

Top executives recognize the importance of the financial ramifications of planning. They are aware that decisions on budgets, appropriations, new product development, plant acquisition, and resource allocations made anywhere within the corporate structure have a far-reaching effect on the total fabric of the organization. They realize that policies and plans to achieve desired corporate objectives are embodied in these decisions.

Today we find the role of the financial manager in a corporation to be of primary importance. The financial manager is being asked to share the increased planning burden, to produce more planning exercises, to explore more alternatives, to provide information in greater detail, and, most significantly, to respond more rapidly.

The financial manager enjoys the confidence of top management because of his contribution to the planning process. The financial people have dedicated themselves to the development of technical competence and the accumulation of the experience necessary to act as consultants and advisers to top management. They have evolved accounting systems and analytic tools

to aid them in performing this function.

The pressures under which the financial manager must now operate are obviously not due to any decrease in his capability. Instead, they stem from the increased demands now being put upon him by top management. The problem facing the financial manager, then, is only in relatively small part that of developing new theory, for the existing body of theory has proved generally adequate. Instead, he must acquire new tools, tools that are appropriate to his changing planning environment, tools that permit him to respond more quickly, more flexibly, and with greater accuracy and precision to requests from top management.

An attempt to use the traditional management structure of the corporation for financial planning creates significant communications problems that do not satisfy the executive response requirements. If management finds it necessary to communicate with all echelons and activities in order to determine the ramifications of a single "I wonder what would happen if" condition, the planning potential of the organization is limited. Yet relying solely on the experience of executives around the board room table does not satisfy today's need for explicit and systematic testing of the impact of change.

In financial simulation we have the potential for an effective solution to this problem. If a sound program—based upon top management participation, an interdisciplinary approach, and a thorough preliminary study phase—is established, this potential can be realized.

The structuring of a financial model is a difficult and sensitive task. We must learn and understand a great deal about the behavior of our organizations before we can produce workable and meaningful models. There is no cheap way to buy the tool. There is no such thing as a general financial simulation model that will act as an effective planning tool for a specific organization. There are no general equations applicable to every organization. While some equations in functional form can be expressed so as to be universal, their real value is in providing a guide for study and development. Even if our study provides a validation of their applicability, we have, in fact, developed our own.

Thus, Burroughs' experience and Burroughs' model are hardly to be taken as universal. Indeed, our experience may not even provide an adequate sample from which to state a set of hard and fast rules. However, our experience has been sufficient to identify some important do's and don't's. And this description of the relationships and circumstances that have produced an effective planning model may be useful as a general guide to those interested in applying the technique.

A LINEAR PROGRAMMING MODEL FOR BUDGETING AND FINANCIAL PLANNING

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The authors examine the potential of linear programming as an approach to financial planning. The model attempts to bring the firm into the best possible end-of-the-period balance sheet position. This is accomplished by stipulating the objective function to be the maximization of net addition to retained earnings with due allowance for technological and management-imposed policy constraints. In addition, analysis of opportunity costs associated with binding constraints are presented by reference to the dual evaluators of the linear programming model.

Introduction

This paper reports on an experiment in applying modern mathematical methods to management problems in budgeting and financial planning. In this experiment the techniques of linear programming and double-entry accounting are joined by means of suitable models and interpretations in order to see what might be gained in the way of a unified approach to total enterprise planning.

Two very general aspects of this study may be identified. Starting from an initial statement of the balance sheet accounts, the first aspect of this study was concerned with devising ways of planning (and identifying) the transaction flows that would, in terms of some relevant objective: (a) bring the corporation into the best possible end-of-the-period balance sheet, and (b) make due allowance for other aspects of management policy, technological limitations, etc. The second aspect of this study was concerned with synthesizing information that could be utilized by management to evaluate all aspects of the problem. That is, it was desired to erect a model which could be used to supply information by means of which a company's management might readily determine the dollar consequences that could be expected to flow from altering the firm's policies or the environment in which it operated, and so on.

To accomplish both of these study objectives simultaneously, the so-called

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direct and dual aspects of a linear programming approach were utilized.[1] Briefly, the direct linear programming model was used to synthesize an optimum program, under given conditions (or constraints) in order to achieve a best end-of-the-period balance sheet as outlined under the first of the study aspects noted above. Then the dual linear programming model was utilized to provide information on how the initially stated conditions might be altered, as outlined above, for the second aspect of this study.

It would have been desirable, of course, to test or otherwise validate (and study) this kind of application in the context of an actual business firm. This was not done. Instead, an application was made in the setting of the business game operated by the Graduate School of Industrial Administration at Carnegie Tech. (Fortunately, this game is sufficiently complicated[2] so that it will bear the weight of the applications of modern operations research techniques like linear programming in more than trivial or unchallenging ways.) The application proceeded as follows. Acting as a hypothetical operations research group[3] within one of the functioning firms, [graduate students synthesized] various aspects of a model and tested [them] against data that were assembled for this purpose. In particular, electronic computer runs[4] were made and compared with actual operations for a representative period of months. Significant improvements were noted; but, since this involved an ex post facto comparison, it cannot be considered a wholly valid test of the model under the conditions of the game where large amounts of uncertainty, the need for coordinated action (as contrasted with coordinated plans), and like considerations must also be handled. For this reason, and also because it will permit us to simplify parts of the (direct) model, we do not propose to emphasize this aspect of the study. We shall try, instead, to emphasize the possible managerial uses of the so-called dual evaluators which emerge from the direct model after developing the direct model in sufficient detail to provide a basis for understanding (a) the actual operating problem that was studied, and (b) the kinds of interrelations that obtain between any pair of direct and dual linear programming models.

Synthesizing the Model

To synthesize the one-period model with which we are concerned, it is convenient to start with the balance sheet shown in Table 1. This is the actual beginning-of-the-period balance sheet for an operating firm. Note that certain accounts have been combined in order to achieve some desirable simplifications.

Note also the letter codes that appear alongside the account captions. By means of the "spread sheet" conventions of double-entry accounting,[5] these

[1] Cf., e.g., Chap. 1 in A. Charnes and W. W. Cooper (2) for an explanation and a managerial interpretation of "direct" and "dual" linear programming models.

[2] This game is built around a detailed model of the packaged detergent industry. For further discussion and description see, e.g., K. J. Cohen, *et al.,* (4); or W. Dill, *et al.,* (6).

[3] This was done actually as part of an assignment for the graduate course in operations research taught by Professor Cooper, and the present paper is based largely on the OR report to the firm in question, prepared as part of that assignment.

[4] Carnegie Tech's Bendix G-20 computer was used for this purpose.

[5] See, e.g., A. Charnes, W. W. Cooper, and Y. Ijiri, (3). See also the references cited therein and especially E. L. Kohler, *A Dictionary for Accountants* (7).

TABLE 1

Beginning Balance Sheet

C: Cash	$ 7,260,000	P: Accounts payable	$ 3,592,000
B: Securities	12,000,000	D: Dividends and taxes payable	2,922,000
R: Accounts receivable	6,999,000	L: Loans payable	4,400,000
G: Finished goods	4,032,000	E: Stockholders' account	46,876,000
M: Raw materials	1,499,000		
F: Fixed assets	26,000,000		
	$57,790,000		$57,790,000

letters will be paired in a way which will provide the debit-credit relations needed for accounting interpretations of the transactions. For instance, observe in Table 2 that the letter pair *CB* refers to the class of entries debit cash, *C*, and credit securities, *B* (= bonds). In each case we employ the variable *X* to refer to the "amount" of the transaction. Thus, in Table 2, X_{CB} = $9,703,000, the amount which is debited to cash and credited to securities. In every case, the debit entry will be symbolized as the left member of a letter pair, and the corresponding credit entry will be symbolized by the letter appearing on the right.

TABLE 2

Optimum Projected Transactions

CB:	Sell securities	$ 9,703,000
CR:	Collect accounts receivable	6,999,000
CL:	New borrowing	—
CE:	Collect interest on securities	6,000
BC:	Buy securities	—
RG:	Cost of sales at standard cost	3,192,000
RE:	Gross profit on sales	12,002,000
GM:	Material consumption (transfer from raw materials to finished goods inventory)	1,300,000
GE:	Variable conversion costs	1,430,000
MP:	Material purchased	1,001,000
PC:	Payment of accounts payable	7,697,000
DC:	Payment of dividends and taxes	7,871,000
LC:	Refund of loans	4,400,000
EF:	Depreciation	217,000
EP:	Manufacturing and operating expenses	4,105,000
ED:	Accruals of income taxes and dividends	4,949,000
	Net addition to retained earnings	4,167,000

Model Constraints

These debit-credit letter pairs for the transaction flows must be supplemented by symbols for the balance sheet (stock)

amounts. To represent these figures, we shall use the symbol K with an appropriate subscript. For instance, $K_C = \$7{,}260{,}000$ refers to the opening cash balance, while $K_B = \$12{,}000{,}000$ refers to the opening balance of the securities account, and so on.

The balance sheet accounts and the transaction flows will, of course, be related by the usual accounting identities. In addition, we need to impose certain conditions (or constraints) which limit the transactions. As a case in point, for this one-period model, we impose

1. The firm's sale of securities cannot exceed the beginning balance in this account—viz.,

$$X_{CB} \leq K_B \tag{1}$$

where, in this case, $K_B = \$12{,}000{,}000$.[6]

In addition to *inequality* constraints, like 1, we also wish to incorporate *equations* which we now illustrate by means of one part of the data for the game:

2. Interest earned is calculated by multiplying the end-of-the-period security balance by the appropriate interest rate; here, the periodic rate is 0.229 per cent. Hence

$$X_{CE} = .00229\,(K_B + X_{BC} - X_{CB}) \tag{2}$$

(K_B is the opening balance for securities, X_{BC} refers to securities purchased during the period, and X_{CB} refers to the cash debits realized by sales of securities during the period. Hence, $(K_B + X_{BC} - X_{CB})$ correctly states the ending balance when, as the Carnegie Tech game requires, all such transactions are effected only in cash.) Applying the indicated interest rate of 0.229 per cent we obtain X_{CE}, the amount which is debited to cash and credited to the stockholder's account.[7]

In the model we use, direct reference to income account details will be avoided. This greatly simplifies the model and does so with no great loss since supplementary analyses of the transactions, with the aid of the model (and its associated spread sheet), can always be undertaken to synthesize an income statement when desired. (See Table 4, below.)

The point to be emphasized is: Our model is one in which *all* constraints must be *simultaneously* satisfied. For example, the X_{CB} which appears in 1 is exactly the same as the one that appears in 2. It will perhaps serve to illustrate our intended meaning by rearranging terms in 1 and 2 and positioning the constant K_B on the right to achieve the pair of expressions:

$$\begin{aligned} .00229\,X_{CB} + X_{CE} - .00229\,X_{BC} &= .00229\,K_B \\ X_{CB} &\leq K_B \end{aligned} \tag{2.1}$$

In particular, note how the variable X_{CB} has been positioned in these expressions. This is intended to reflect the simultaneity aspect of the constraints for this model. If, in any solution, an amount is assigned to the variable X_{CB} in one of these expressions, then this same value must be assigned to this variable in the other expression. The admissible values for the variables must therefore satisfy *all* of the constraints simultaneously.

Bearing this in mind, we proceed to formulate the remaining constraints:

3. Since the firm's terms of sale are 30 days net, its maximum collection of receivable during the month is given by the beginning balance in the receivables account.

$$X_{CR} \leq K_R \tag{3}$$

[6] All constraints will represent dollar limits or their equivalents.

[7] In the Carnegie Tech. Game, all interest income is realized as immediate cash income, and the price of the bond is held constant throughout the Game periods.

4. The beginning-of-the-period cash balance limits the purchase of securities.

$$X_{BC} \leq K_C \tag{4}$$

5. The firm's per unit selling price during the period studied was \$9.996+; its per unit standard cost of production was \$2.10. The following constraint represents the "contribution"[8] on a unit sale in terms of the corresponding deduction from finished goods inventory.

$$X_{RE} = 3.76\, X_{RG} \tag{5}$$

6. Standard cost for a unit of finished goods (\$2.10/unit) includes material cost (X_{GM} = \$1.00/unit) and conversion cost (X_{GE} = \$1.10/unit), which consists of direct labor cost and direct overhead.

$$X_{GE} = 1.1\, X_{GM} \tag{6}$$

7. Production capacity limits conversion during the period. Here, production capacity is expressed in the value of raw materials (at standard cost) that can be converted.

$$X_{GM} \leq 1{,}300{,}000 \tag{7}$$

8. Conversion is also limited to raw materials on hand at the beginning of the period.[9]

$$X_{GM} \leq K_M \tag{8}$$

9. Market conditions limit sales in the current period to 2,000,000 units[10] (\$4,200,000 at standard cost).

$$X_{RG} \leq 4{,}200{,}000 \tag{9}$$

10. Sales during the period are further limited to the beginning balance of completed units.[11]

$$X_{RG} \leq K_G \tag{10}$$

11. Repayment of loans is limited by the outstanding loan balance at the beginning of the period.

$$X_{LC} \leq K_L \tag{11}$$

12. Because the firm is allowed 30 days for payment of materials purchased, the payment of accounts payable is limited to the sum of the beginning balance of accounts payable plus expenses of the current period.

$$X_{PC} \leq K_P + X_{EP} \tag{12}$$

13. Monthly depreciation charges are .833 per cent of the net fixed assets owned at the beginning-of-period.

$$X_{EF} = .00833\, K_F \tag{13}$$

14. Costs to be incurred during the current period include manufacturing costs (other than materials) and operating costs which consist of the following four items: (a) fixed operating expenses, \$2,675,000; (b) variable conversion cost, X_{GE}; (c) effective interest penalty for discounts not taken on accounts payable (3.09 per cent per period); and (d) interest (periodic rate, .291 per cent) on loans payable at the end of the period.

$$\begin{aligned} X_{EP} = {} & 2{,}675{,}000 + X_{GE} + .0309 \\ & (K_P + X_{EP} - X_{PC}) \\ & + .00291\, (K_L + X_{CL} - X_{LC}) \end{aligned} \tag{14}$$

[8] "Contribution" is the term used here to describe the difference between revenue and incremental, variable, or direct cost. Thus, each unit sold gives rise to a contribution of \$7.896 (\$9.996+ − 2.10), which is 3.76 · \$2.10.

[9] In this case, K_M = \$1,499,000 so that the preceding constraint, 7, is controlling. We have, however, represented both constraints for the sake of completeness in cases where K_M < \$1,300,000.

[10] Obtained from the relevant market forecast, determined as an expected rate, a maximum and a minimum. The maximum is entered here as an exact upper limit for subsequent study by reference to the relevant dual evaluators.

[11] Cf. footnote 10. It should also be observed that this constraint is intended to reflect the lag on shipments from the plant to the relevant distribution centers.

15. Income tax is accrued at 52 per cent of the net profit. In addition, the firm's policy is to declare a dividend equal to \$83,000 plus (minus) 5 per cent of the excess (shortage) of what it considers a standard net profit after taxes, \$1,860,000.

$$X_{ED} = .52(X_{CE} + X_{RE} + X_{GE} - X_{EF} - X_{EP}) + 83{,}000 + .05[.48(X_{CE} + X_{RE} + X_{GE} - X_{EF} - X_{EP}) - 1{,}860{,}000]$$

Simplifying,

$$X_{ED} = .544\,X_{CE} + .544\,X_{RE} + .544\,X_{GE} - .544\,X_{EF} - .544\,X_{EP} - 10{,}000 \tag{15}$$

16. Company policy requires a minimum cash balance of \$4,000,000 at the end of each period.

$$K_C + X_{CB} + X_{CR} + X_{CL} + X_{CE} - X_{BC} - X_{PC} - X_{DC} - X_{LC} \geq 4{,}000{,}000 \tag{16}$$

17. Because of an impending price rise in the next period—i.e., in the period following the one under study—the firm requires the ending balance of finished goods inventory to be at least as great as the minimum sales expected during the following period (expected sales of 1,700,000 units at \$2.10 standard cost/unit, or \$3,750,000).[12]

$$K_G + X_{GM} + X_{GE} - X_{RG} \geq 3{,}570{,}000 \tag{17}$$

18. The firm also expects to produce 1,200,000 units in the next period. Thus, the ending balance of raw materials must be sufficient for this expected production. (At \$1.00 raw material cost/unit, the end of the period raw materials balance must be \$1,200,000.)[13]

$$K_M + X_{MP} - X_{GM} \geq 1{,}200{,}000 \tag{18}$$

19. All outstanding income taxes payable and dividends declared, including those accrued or declared during the period, have to be paid by the end of the current period.

$$K_D + X_{ED} - X_{DC} = 0 \tag{19}$$

In addition to these constraints, all transaction variables (X's) are required to be non-negative. This is done to avoid any confusion between the debit and credit entries which would otherwise have to be given a reverse (credit-debit) interpretation for negative values of any X. Either way of proceeding can be elected, but it simplifies the exposition merely to arrange the model so that the non-negativity condition can be enforced on all variables.

Statement of Objectives and Completion of the Model

As indicated, an explicit statement of the profit-and-loss accounts (in their usual sense) is eliminated in the model that we are synthesizing. Thus, in place of assuming that profit maximizing is controlling, we consider that this firm wishes to maximize its net addition to retained earnings.[14] This is given by

[12] Note that this amount, too, is subject to treatment by means of the dual evaluators. For instance, such an analysis will show how much is being lost from current profit opportunities in order to provide for the future in this manner.

[13] See preceding footnote.

[14] It is not proposed to enter into a statement of whether this is the proper objective or whether any *one* objective is ever proper for a business. If, for instance, break-even or other objectives are wanted, then recourse may be had to the devices discussed in A. Charnes, W. W. Cooper, and Y. Ijiri (3), *op. cit.* Some caution may be needed in considering *multiple* objectives since policy conditions (like "stable employment," etc.) can be reflected in the constraints. On the other hand, when multiple objectives are desired, recourse may be had to approaches like those given in Chap. 9 of Charnes and Cooper (2), *op. cit.*

Net additions to retained earnings
$= X_{CE} + X_{RE} + X_{GE} - X_{EF} - X_{EP} - X_{ED}$

Because the objective is maximization, we can refer to the preceding constraint details and set forth the full linear programming models as

$$\text{maximize } X_{CE} + X_{RE} + X_{GE} - X_{EF} - X_{EP} - X_{ED}$$

subject to

$$X_{CE} - .00229\,X_{BC} + .00229\,X_{CB} = .00229\,K_B \quad (1)$$
$$X_{CB} \leq K_B \quad (2)$$
$$X_{CR} \leq K_R \quad (3)$$
$$X_{BC} \leq K_C \quad (4)$$
$$X_{RE} - 3.76\,X_{RG} = 0 \quad (5)$$
$$X_{GE} - 1.1\,X_{GM} = 0 \quad (6)$$
$$X_{GM} \leq 1{,}300{,}000 \quad (7)$$
$$X_{GM} \leq K_M \quad (8)$$
$$X_{RG} \leq 4{,}200{,}000 \quad (9)$$
$$X_{RG} \leq K_G \quad (10)$$
$$X_{LC} \leq K_L \quad (11)$$
$$X_{PC} - X_{EP} \leq K_P \quad (12)$$
$$X_{EF} = .00833\,K_F \quad (13)$$
$$X_{EP} - X_{GE} - .0309\,X_{EP} + .0309\,X_{PC} - .00291\,X_{CL} + .00291\,X_{LC} = 2{,}675{,}000 + .0309\,K_P + .00291\,K_L \quad (14)$$
$$X_{ED} - .544\,X_{CE} - .544\,X_{RE} - .544\,X_{GE} + .544\,X_{EF} + .544\,X_{EP} = 10{,}000 \quad (15)$$
$$X_{CB} + X_{CR} + X_{CL} + X_{CE} - X_{BC} - X_{PC} - X_{DC} - X_{LC} \geq 4{,}000{,}000 - K_C \quad (16)$$
$$X_{GM} + X_{GE} - X_{RG} \geq 3{,}570{,}000 - K_G \quad (17)$$
$$X_{MP} - X_{GM} \geq 1{,}200{,}000 - K_M \quad (18)$$
$$X_{ED} - X_{DC} = -K_D \quad (19)$$
$$X_{CB}, X_{CR}, X_{CL}, X_{CE}, X_{BC}, X_{RG}, X_{RE}, X_{GM}, X_{GE}, X_{MP}, X_{PC}, X_{DC}, X_{LC}, X_{EF}, X_{EP}, X_{ED} \geq 0$$

That is, we are to search for amounts X_{ij} which satisfy all constraints, including non-negativity for all variables, and, among the entire collection of such values, we are to single out one set that makes the net addition to retained earnings a maximum. The solution methods of linear programming—e.g., the simplex method[15]—are designed to produce exactly this result.

The Results

By substituting the figures in the beginning balance sheet (Table 1) for the K's in the above constraints and by applying the simplex method, a solution to the above problem was readily achieved. We now summarize the results in the following series of tables. In Table 2 we list the transactions which achieve the maximum possible net addition to retained earnings.

Next, we utilize this information to obtain the following projections of the balance sheet and income statement (Tables 3 and 4).

Notice that we now have the main documents that are usually deemed to be pertinent for financial planning purposes. Additional documents—e.g., flow of funds statements, cash budgets, etc.—can also be generated if desired.[16] Instead of pursuing these, we intend to indicate how the results of this analysis can be used for planning and execution by various kinds of management. The details of Table 2 lend themselves to ready translation for the direction of operating managers, or other persons, who are not immediately concerned

[15] We used this method as one part of the available G-20 electronic computer code without attempting to apply or devise other, possibly more efficient, methods. For further remarks on this topic, see Charnes, Cooper, and Ijiri (3), *op. cit.*

[16] See Charnes, Cooper, and Ijiri (3), *op. cit.*, for further discussion.

TABLE 3

Projected Balance Sheet, End of Period

C: Cash	$ 4,000,000	P: Accounts payable	$ 1,001,000
B: Securities	2,297,000	D: Dividends and taxes payable	—
R: Accounts receivable	15,194,000	L: Loans payable	—
G: Finished goods	3,570,000	E: Stockholders' account	51,043,000
M: Raw materials	1,200,000		
F: Fixed assets	25,783,000		
	$52,044,000		$52,044,000

TABLE 4

Projected Income Statement for the Period

Sales (RG + RE)		$15,194,000
Incremental cost (RG)		3,192,000
Contribution (RE)		$12,002,000
Manufacturing costs and operating expenses (EP)	$4,105,000	
Depreciation (EF)	217,000	
Manufacturing costs charged to finished goods (GE)	−1,430,000	
Unabsorbed manufacturing costs and operating expenses		2,892,000
Operating profit		$ 9,110,000
Interest income (CE)		6,000
Net income before tax		$ 9,116,000
Accruals of income taxes and dividends (ED)		4,949,000
Net addition to retained earnings		$ 4,167,000

with the overall aspects of financial planning. For instance, the production manager may be directly instructed to plan to produce $2,730,000 worth of finished goods during this period and further to allocate $1,300,000 of this amount for the purchase of raw materials and to expend the rest ($1,430,000) on conversion costs. In turn, the purchasing department may be instructed to purchase $1,001,000 worth of raw materials, and so on.

Of course, the usual information for a coordinated assessment and review by top management is also available in the form of projected balance sheets, income statements, etc. In addition, the linear programming solution provides valuable by-product information in the form of the dual evaluators.[17] We propose therefore to elaborate on this topic in the next section and then show how this information can be assembled to form a new type of accounting document for use in integrated management planning.

[17] The G-20 code (like most linear programming codes) provides these data automatically, at the end of its run, as well as other (equally valuable) results which enable the user to test the program's sensitivity to errors in the data, etc. See, e.g., Charnes and Cooper (2), *op. cit.*, Chap. XIII for a discussion in the context of the so-called revised simplex code for IBM computers.

An Accounting Statement for the Dual Evaluators as Opportunity Costs

A dual evaluator, at least in a managerial-accounting-economics context, indicates the change in net addition to retained earnings that can be secured if the constraint corresponding to the given evaluator were relaxed by one dollar. For example, the dual evaluator of constraint number 7 (production capacity) has a value of $3.594936. This means that if production capacity were increased so that exactly one additional dollar's worth of raw material can be processed, then retained earnings will be increased by $3.594936. This figure, which is obtained (automatically) as a so-called evaluator really summarizes a whole complex of interrelated opportunities. Hence, some further accounting aids to managerial interpretations and uses are indicated.

In order to show that the dual evaluators take into account every constraint of the model in *mutatis mutandis* fashion, the evaluator of production capacity will now be analyzed in more detail.[18] Let it be desired to alter the firm's raw material processing capacity by one unit. This activates a whole complex of transactions which are set forth in Table 5.

Notice that the end result is the $3.59 figure which was predicted by the dual evaluator; also notice that each of the indicated transactions are carried out optimally (relative to one another) in order to produce this optimal return from the indicated increase of one unit of capacity. The single figure of $3.59 summarizes all of these transactions, but it needs accounting elaboration if the purposes of managerial use and understanding are to

TABLE 5

Analysis of Opportunity Costs*: $3.59 Per Unit Increase in Production Capacity

1.	Incremental sales resulting		$9.996000
	Less: Cost of incremental sales		2.100000
2.	Contribution		7.896000
3.	Deduct: Income taxes and dividends (54.4%)		4.295424
4.	Net retained from sales after taxes and dividends		3.600576
5.	Deduct: Opportunity cost of the cash needed to finance expansion:		
	Cash required for raw materials†	$ —	
5a.	Conversion to finished product	1.100000	
	Total	$1.100000	
5b.	Add: Cash required for income taxes and dividends	4.295424	
5c.	Total cash required	$5.395424	
6.	Total of interest earnings foregone on securities sold ($5.395424 @ 0.00104533)		0.005640
7.	Net retained realization per unit increase in production capacity		$3.594936

* This statement is based on optimal adjustments being effected in all pertinent transactions.
† All required raw material is available from inventory on hand.

[18] See Charnes and Cooper (2), *op. cit.*, for further elaboration and distinctions between *ceteris paribus* and *mutatis mutandis* approaches.

be adequately served. The above statement is intended to supply this kind of service.

The data of Table 5 were drawn from the by-product results furnished automatically by the computer calculations after appropriate supplementation by economic-accounting considerations. We now elaborate on this as follows:

In 1 we observe that the incremental capacity increase has resulted in a sale of goods. The needed raw material is presently on hand, since K_M = \$1,499,000 (Table 1) is greater than X_{GM} = \$1,300,000 (Table 2). Therefore, an adidtional raw material unit is drawn from inventory. This unit is processed at \$1.10 conversion of finished goods which, valued at standard, costs \$2.10. The unit of finished goods can be sold at once, since the firm has unfulfilled demand in the present month of \$1,008,000 of product (valued at standard cost—see constraint No. 9, remembering X_{RG} = \$3,192,000).

Segments 2, 3, and 4 give the net profit realized from this sale as determined by constraints 5 and 15 of the model.

The transaction analysis is not yet complete, as the gross profit (\$3.600576) is higher than the dual evaluator (\$3.59436). The difference (\$.00564) can be accounted for by turning to the cash account and recalling that the program has pushed up against the \$4,000,000 stipulated minimum balance. Therefore, the additional cash outlays needed for production must be obtained in one of three ways: (a) sell securities at the monthly interest rate 0.229 per cent; (b) borrow from bank at the monthly interest rate 0.291 per cent; (c) postpone payments on accounts payable at a monthly interest rate 3.09 per cent. The least costly of these three ways is obviously achieved in the sale of securities. The \$.00564 shown opposite 6 in the above statement represents the opportunity cost incurred because of the interest income that must be foregone if securities are sold to obtain the needed cash. This is derived as follows: 5a and 5b give the amount of cash needed to increase production by one unit. 5a represents the conversion cost which is paid at the end of the period. 5b represents dividends and taxes payable on the profit generated in 4, and cash must be obtained to pay these at the end of the period. The total cash requirement is therefore the sum of 5a and 5b, or \$5.395424,[19] which is the figure shown opposite 5c. 6 multiplies the number of dollars needed by the opportunity cost per dollar to obtain the total opportunity cost of obtaining cash.

The opportunity cost per dollar is obtained via the following reasoning:

The firm foregoes interest income of \$.00229 for every dollar of securities sold. However, the loss is reduced to \$.00104424 by taking into account savings on taxes and dividends. Since the interest income would normally be collected in cash at the end of the period, the \$.00104424 of income foregone reduces the end of period cash balance by \$.00104424. This reduction in cash balance violates constraint No. 16 (minimum cash balance constraint) and to compensate for this reduction the firm must sell an additional \$.00104424 of securities and forego (.00104424 × .00104424) dollars of net interest income, as well as (.00104424 × .00104424) reduction in the cash balance.

The total reduction of net profits after taxes and dividends resulting from this sale of securities needed to obtain an additional dollar of cash is given by the sum of the infinite series:

$$.00104424 + (.00104424)^2 + (.00104424)^3 + \cdots$$
$$= \frac{.00104424}{1 - .00104424} = .00104533$$

Therefore .00104533 appears as the unit opportunity cost in 6.

Finally, in 7 we see that the net effect of relaxing the production capacity constraint by one unit is equal to the difference between net profit (after taxes and dividends)

[19] Note that two other cash flows (accounts receivable and payments on raw material accounts) are affected by the capacity increase. However, they have no effect on the flow in the present period, as they are not received (or paid) until the following period.

realized from the sale of goods and the opportunity cost of securing additional cash required. That is, \$3.600576 − \$.005640 = \$3.594936. This figure is precisely equal to the dual evaluator associated with production capacity.

Notice in particular that any one dual evaluator provides the opportunity cost information that is relevant when *every* possible transaction is altered to a new optimum level in response to a change anywhere in the system. This is, in fact, the intended meaning of the term *mutatis mutandis,* which has been accorded to this determination of opportunity costs in contrast to other approaches which assume that only a few variables are adjusted while all others are held constant.

Of course, we have singled out only a small portion of the total dual evaluator information printed out by a computer at the end of a run on a linear programming model. Evidently further extensions can be made by considering collections of these evaluators simultaneously and still other kinds of extensions can also be made. The main point here is that the *mutatis mutandis* approach will generally involve a complex series of transaction interactions. Technically speaking there is no real trouble in assessing the dual evaluators. On the other hand, some forms of guidance and assistance undoubtedly have to be supplied if management is to make intelligent and understanding uses of this information. One form of assistance has been suggested by the accounting statement which we have exhibited. Undoubtedly other kinds of statements will also be devised, especially where more complex transaction interactions are considered. Some exercise of ingenuity and some period of experimentation will be required for this purpose.

Conclusion

We now try to point out some of the conclusions and further elaborations suggested by this study. First, we should observe that linear programming is not the only possible mathematical method of approach to accounting and financial planning.[20] It does, however, offer a highly flexible instrument and is associated with an extremely sharp and general (underlying) mathematical theory. Our analysis and interpretation of the dual evaluators should be taken as partially illustrative of the type of further extensions that are readily available from the linear programming model. Sensitivity analysis offers still another alternative course of immediate extensions which would show the effect of changes in the objective function or constraints (including additions of new variables and constraints) on the optimum solution of the model. As in the above, all sensitivity changes within any specific part of the model are evaluated in terms of their effect on the entire model. In general, this evaluation can be done without re-solving the entire problem.

Other applications of linear programming to accounting have shown the relationships between programming to goals and break-even budgeting.[21] This could be combined with our application to form a unified approach to planning when multiple (and sometimes conflicting) objectives exist among the various divisions of a firm. Such an approach might be in order, for example, to determine a system of transfer prices for guiding decentralized

[20] For example, see C. P. Bonini (1); or R. M. Cyert, J. Davidson, and G. Thompson (5).

[21] Charnes, A., W. W. Cooper, and Y. Ijiri (3) *op. cit.*

operations in a way that will produce the best *overall* results from each department's operations. These applications are available as a result of previous research in the theory and applications of linear programming. Additional research might produce further advantages if it were devoted to, say, investigating accounting models and applications as such. As Charnes, *et al.*[22] have shown, the network features of accounting models offer promising avenues of exploitation. With suitably arranged objective functions, linear programming and simulation approaches can be joined together with further increases in the scope and power of each.

Finally, all of these topics are closely associated with the rapidly evolving developments and uses of electronic computers for business purposes. Further research in this direction is also warranted if the full value of these devices for managerial accounting applications is to be achieved.

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AN ACCOUNTING SYSTEM STRUCTURED ON A LINEAR PROGRAMMING MODEL

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In traditional internal accounting systems budgets are prepared by organizational responsibility centers and, subsequently, compared with actual results by such well-known techniques as standard-cost variance analysis. This approach has two basic limitations. First, certain data inputs of decision models are not incorporated in the variance analysis. Second, no recognition is accorded to revisions of original plans. Using a linear programming formulation of the firm's planning process, the proposed control system compares the firm's accomplishments with what it deems ex post it should have accomplished.

The increasing use of well-defined decision processes, such as linear programming and inventory models, raises certain issues as to the appropriateness of the internal accounting techniques used in conjunction with their application. In the typical cost accounting system, costs are classified by responsibility and then budgeted, and later the actual results are compared, using the well known techniques of standard cost variance analysis. Extending this traditional control technique to situations involving well-defined decision models has two obvious disadvantages: It often leaves certain data inputs to the decision model outside of the analysis—for example, technical coefficients or prices of substitute materials—and it ignores the decision alterations implied by many of the deviations encountered.

One possible method of alleviating these shortcomings, as suggested in a recent publication,[1] is to extend the traditional accounting technique to include all inputs to the decision model and to provide for revision of the original decision based on the deviations encountered. That is, it is possible to provide information simultaneously for control of performance as well as the decision by structuring the accounting control system on the specific decision model employed. The mechanical aspects, implications, and pilot application results of such a structured approach are discussed in this paper. Since any detailed discussion must, by its very nature, be based on a specific decision model, we postulate for purposes of exposition and application a linear programming formulation of the firm's planning process.

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[1] N. Dopuch, J. Birnberg, and J. Demski, "An Extension of Standard Cost Variance Analysis," *The Accounting Review* (July, 1967).

Description of the Structured System

In this structured accounting system the firm is viewed as periodically resolving its planning model on the basis of re-estimated data inputs and, perhaps, structural changes in the model itself. Following determination of a particular planning period's program, called the ex ante program, the program is implemented and actual results are observed. During the time

interval between implementation and observation of final results, there may also be intraperiod revision of this ex ante program. The traditional accounting analysis stops at this point and compares these observed results with the (possibly revised) ex ante results, using variance analysis techniques to assess the dollar significance of each individual deviation.

The proposed system carries this traditional analysis one step further. This is accomplished by determination of an ex post optimum program. On the basis of additional information acquired during implementation of the ex ante program, the firm revises or confirms its original data input estimates. (This revision/confirmation may be viewed as part of the process of resolving the model for the following period.) These revised estimates are the ones the firm would have used to determine the ex ante program had it forecast correctly. The program implied by these revised estimates is called the ex post program.

We now have three sets of results: the ex ante, the observed, and the ex post. The difference between ex ante and ex post results is a crude measure of the firm's forecasting ability. It is the difference between what the firm planned to do during the particular period and what it should have planned to do. Similarly, the difference between ex post and observed results is the difference between what the firm should have accomplished during the period and what it actually did accomplish. It is the opportunity cost to the firm of not using its fixed facilities to maximum advantage. Specifically, it is the opportunity cost of nonoptimal capacity utilization, and, for obvious reasons, this structured accounting system is called an ex post system.

These differences among the ex ante, observed, and ex post results are analyzed by application of traditional variance analysis techniques. No attempt is made in the paper to assess the statistical significance of the various deviations.

Before proceeding to a more rigorous description of the ex post system it will be advantageous to delineate the more important assumptions on which it is formulated. This is the task of the following section.

Some Basic Assumptions in the Ex Post System

Our structured ex post accounting system is based on four major assumptions: (1) that the firm employs some specific well-defined formulation of its planning process, (2) that management possesses the ability to distinguish between avoidable and unavoidable variances or deviations, (3) that feedback control information is useful, and (4) that the search for possible opportunities can be limited in scope, for our purposes, to the existing planning model. These are discussed in turn.

The first assumption, that the firm employs some specific well-defined formulation of its planning process, is almost too obvious to mention. However, it must be remembered that any formal decision model—such as inventory, linear programming, or queuing —that is employed in some decision context can be used as a basis for structuring the accounting system. The present discussion, though, is limited to situations in which the linear programming model is applicable. In addition, this structuring can be pursued at any level in an organization. It can, for example, be applied in some individual production department where a specific scheduling model is employed or, on the other hand, to an entire firm where some master planning model for output mix and quantities is employed.

The second major assumption, ability to distinguish between avoidable and unavoidable deviations, is fundamental to any control system. Actually, management must possess the ability to determine a given deviation's source if it is to distinguish the avoidable from the unavoidable deviations. This is not, however, an easy task, because any observed deviation of an actual from a planned result can be the result of prediction errors, performance failures, measurement errors, model errors (approximations or errors in constructing and using the planning model), randomness, or some combination of these five sources. Since each source may require a different response—for example, alter performance, the decision, or the model—and since each has different implications for future planning decisions, ability to distinguish among them is vital.

This ability to determine a deviation's source is also related to the third assumption, usefulness of feedback control information. Feedback usefulness implies that feedback leads in some way to learning and/or remedial action. And, since any deviation signaled by the feedback process may arise from a multiplicity of sources, occurrence of either learning or remedial action is predicated on an ability to establish the deviation's source and controllability. The feedback assumption is even stronger. It implies that once the deviation's source is determined, this knowledge is useful. Otherwise there is no point in developing the information.

The fourth assumption is that the planning model and perceived deviations are sufficient to reflect and measure all lost opportunities. That is, the search for opportunities is limited to the planning model and feedback process. This is a critical limitation; any model coupled with normal feedback cannot be expected to reflect or contain all opportunities. But at the same time, a realistic approach is required; this is the only method of formally synthesizing opportunities. The accountant must take the firm's formal decision models as a given, where such models exist, and this course is followed here.[2]

Having stated the major assumptions on which the system is based, we shall now develop the particulars of ex post analysis based on the linear programming model.

The Ex Post System Based on the Linear Programming Model

In the linear programming model the firm wishes to maximize CX subject to the conditions that (1) $AX=b$ and (2) $X\geq 0$, where C in an n-element row vector of the contribution margins of the n products, X is an n-element column vector of the output quantities of the n products, $AX=b$ represents the production, demand, legal, policy, and other constraints faced by the firm, and $X\geq 0$ represents the non-negativity restrictions on the n products. The main constraints ($AX=b$) are stated in equality form, without loss of generality, through the addition of appropriate slack vectors.

The data inputs to the model are contained in the (A, b, C) triple. These are assumed to be known constants. Let (A^a, b^a, C^a) be the input values used to determine the original (perhaps adjusted) optimum plan, X^a, for the current planning period. These are called the ex ante inputs and optimum program. Also, let (A^o, b^o, C^o) and

[2] In reality, the accountant has three alternatives: take the formal decision models as given, improve them, or ignore them. Taking a stand for improvement is rather presumptuous. Ignoring them and relying on the traditional accounting model, as evidenced by the pilot application described later in the paper, is inadequate.

X^o be the input values and output quantities actually observed during the period. Finally, let (A^p, b^p, C^p) be the input values that would have been used to determine the ex ante program had all additional information acquired up to the time of analysis been available at the beginning of the period.[3] These are called the ex post inputs and the associated program X^p, the ex post (optimum) program.

Total net income for the period, NI, may now be expressed (omitting units) as:

$$NI = CX - F$$

where F, a scalar, is the total fixed cost. Following through with the notation, ex ante or planned net income for the period is

$$NI^a = C^aX^a - F^a,$$

observed net income is

$$NI^o = C^oX^o - F^o,$$

and ex post net income is

$$NI^p = C^pX^p - F^p.$$

Ex Post Analysis

Application of traditional variance analysis techniques to the differences among ex ante, observed, and ex post net income is the central feature of ex post analysis. This extension of the traditional analysis is easily accomplished by observing that the difference between ex ante and observed net income or profit can be divided into two components:

$$NI^a - NI^o = (NI^a - NI^p) + (NI^p - NI^o)$$

[3] The discussion assumes that all deviations occur at the beginning of the period and persist throughout; the converse is readily handled by introducing new products into the model and appropriately altering the constraint set.

The first term, the difference between ex ante and ex post optimum net income, is a rough indicator of the efficiency of the planning process. Analysis of the causal factors here should be of considerable importance in directing or indicating the need for additional forecasting efforts. The second term, the difference between ex post and actual net income, is the difference between what the firm could have accomplished, given the additional information acquired up to the time of analysis, and what it actually did accomplish. In this sense it is an opportunity cost—the opportunity cost of nonoptimal capacity utilization.[4]

Ideally, the opportunity cost of each individual data input and output deviation should be measured. But, as in traditional variance analysis, a unique significance determination is generally impossible because of joint product terms. To appreciate fully the nature of this limitation, examine the $(NI^p - NI^o)$ opportunity cost variance:

$$\begin{aligned} NI^o &= C^oX^o - F^o \\ NI^p &= C^pX^p - F^p \\ &= (C^o + \Delta C)(X^o + \Delta X) \\ &\quad - (F^o + \Delta F) \end{aligned}$$

Hence,

$$\begin{aligned} (NI^p - NI^o) &= (C^o + \Delta C)(X^o + \Delta X) \\ &\quad - (F^o + \Delta F) - C^oX^o \\ &\quad + F^o \\ &= C^o\Delta X + \Delta CX^o \\ &\quad + \Delta C\Delta X - \Delta F \end{aligned}$$

All that can be said for certain is that the importance of these jointness difficulties will depend on the actual data.

It will now be helpful to compare

[4] It is nonoptimal in the sense that NIP is the best the firm deems it could have done, and the term is therefore always nonnegative. And it is capacity utilization in the sense that this is an indicator, measured in terms of the firm's objectives as expressed in its decision model, of what it did with its fixed facilities.

this ex post approach with the cost-volume-mix or profit-variation analysis which is generally associated with variance analysis in a multiproduct firm. This traditional analysis is accomplished by analyzing the differences among ex ante, observed, and adjusted net income, where the adjusted net income, NI^b, is defined as follows:

$$NI^b = C^a X^o - F^a$$

That is, the adjusted net income represents ex ante or planned results for the actual sales volume and mix.

The analysis is completed by factoring the total difference to be explained, $NI^a - NI^o$, into two separate terms by inserting the adjusted budget:

$$NI^a - NI^o = (NI^a - NI^b) + (NI^b - NI^o)$$

The first term, the difference between planned and standard income for the volume and mix obtained, represents the effect of volume and mix variations, assuming standard performance. Similarly, the second term, the difference between standard income for the volume and mix actually obtained and actual income, represents the effects of nonstandard performance, given the observed volume and mix.

As mentioned above, strict reliance on this traditional system is disadvantageous because it does not monitor all inputs to the planning model and because it does not assess the program revisions implied by some of the deviations. These deficiencies are discussed in turn.

Ability of Traditional and Ex Post Systems to Signal Deviations in Data Inputs

To emphasize the fact that the traditional analysis is strictly limited to signaling deviations in the cost and revenue items associated with those products actually planned and/or produced (that is, with basis products), we redefine the relevant net income terms in the following manner:

$$NI^a = C_B^a X_B^a - F^a$$
$$NI^o = C_B^o X_B^o - F^o$$
$$NI^p = C_B^p X_B^p - F^p$$

where the B subscript denotes that C, X, and A have been partitioned so that X_B contains only those products planned and/or produced—that is, only those products in the basis.

This admittedly cumbersome notation serves the very useful purpose of explicitly identifying the proper subset of data inputs to the planning model contained in the traditional analysis. In addition to elements in the output vector X, the traditional cost-volume-mix analysis monitors explicitly the following elements in the (A, b, C) triple:

$$c_j^a \quad j \in B$$
$$c_j^o \quad j \in B$$

It also monitors explicitly the following elements *if* deviations in these elements alter some c_j coefficient in the basis:

$$b_i^a$$
$$a_{ij}^a \quad j \in B$$
$$b_i^o$$
$$a_{ij}^o \quad j \in B$$

For example, if some c_j coefficient is dependent on some set of a_{ij} coefficients, changes in these particular a_{ij} coefficients will change the respective c_j; and, consequently, if the particular j is in the basis, this alternation in a_{ij} will be signaled by the traditional system—because it produces an alteration in some c_j coefficient contained in the basis.

Furthermore, since the basis, B, is a function of the model's structure and data input triple, the entire ex ante triple is implicitly contained in the analysis. And to the extent that actual output depends on the associated basis and right-hand side elements (spe-

cifically, $X^o = B^{o-1}b^o$), the basis elements of the observed triple are also implicitly contained in the analysis.

Thus, at a minimum, explicitly or implicitly, all observed data input elements not contained in the observed basis are ignored in this traditional comparison of planned with actual results.

In contrast, the ex post system explicitly or implicitly monitors all elements in the ex ante, observed, and ex post triples, as well as their associated output vectors. It explicitly monitors all elements explicitly monitored by the traditional system as well as c_j^p $(j \in B)$ and those b_i^p and a_{ij}^p $(j \in B)$ elements in which deviations alter some c_j^p $(j \in B)$. Also, since (A^p, b^p, C^p) is partially determined by (A^a, b^a, C^a) and (A^o, b^o, C^o) and X^p is a function of the ex post structure of the model and input triple, all model deviations are implicitly monitored by the ex post system.

Hence, the ex post system is clearly superior to the traditional accounting system in terms of its ability to signal deviations, because it will signal a deviation in any data input element in the model while the traditional system ignores some of these deviations. In addition, and in direct contrast with the traditional model, these signals are provided with direct reference to certain decision requirements. They are, to be precise, provided within an opportunity cost framework. A series of examples will best illustrate this.

Ability of Traditional and Ex Post Systems to Measure Foregone Opportunities

Consider a firm with two products, X_1 and X_2, and two production departments, A and B. The products have contribution margins of \$1 and \$3, respectively, and the two departments have capacities of 400 and 600 units, respectively. Further, assume that product X_1 requires one unit of time in each department while X_2 requires one unit in A and two in B. Then, omitting units, the firm's objective is to maximize $X_1 + 3X_2$ subject to the conditions that

$$X_1 + X_2 \leq 400$$
$$X_1 + 2X_2 \leq 600$$

and $X_1, X_2 \geq 0$.

Adding two slack variables, X_3 and X_4, we restate the constraint set in equality form:

$$X_1 + X_2 + X_3 = 400$$
$$X_1 + 2X_2 + X_4 = 600$$

The initial linear programming tableau is:

C_B	b	X_1	X_2	X_3	X_4
0	400	1	1	1	0
0	600	1	2	0	1
$z_j - c_j$		−1	−3	0	0

and the final tableau is as follows:

0	100	$\frac{1}{2}$	0	1	$-\frac{1}{2}$
3	300	$\frac{1}{2}$	1	0	$\frac{1}{2}$
		$\frac{1}{2}$	0	0	$\frac{3}{2}$

with $(X^a)^T = (0, 300, 100, 0)$ and $C^a X^a = 900$.[5]

Example 1

Assume, now, that an unavoidable deviation occurs in product X_2's con-

[5] That is,

$$C^a X^a = \sum_{j=1}^{n} c_j^a x_j^a = (1)(0) + (3)(300) + (0)(100) + (0)(0) = 900.$$

Also, $(X^a)^T$ merely denotes that we have transposed X^a—shown it as a row vector instead of a column vector.

tribution margin such that the observed c_2 is \$1 instead of the ex ante value of \$3. Further, assume that observed output is identical to ex ante output. Then, $C^o = C^p = (1, 1, 0, 0)$; $(X^a)^T = (X^o)^T = (0, 300, 100, 0)$; $b^a = b^o = b^p$; $A^a = A^o = A^p$; and

$$C^oX^o = (1, 1, 0, 0)\begin{bmatrix} 0 \\ 300 \\ 100 \\ 0 \end{bmatrix} = 300$$

The final tableau for determining X^p is:

1	200	1	0	2	−1
1	200	0	1	−1	1
		0	0	1	0

with $(X^p)^T = (200, 200, 0, 0)$ and $C^pX^p = 400$.

For simplicity we shall ignore fixed cost in this and the following examples. Therefore, $NI = CX$; hence,

$$\begin{aligned} NI^a - NI^o &= (NI^a - NI^p) + (NI^p - NI^o) \\ &= (C^aX^a - C^pX^p) + (C^pX^p - C^oX^o) \\ &= (900 - 400) + (400 - 300) \\ &= 500 + 100 \end{aligned}$$

The 500 variance is the difference between planned and ex post optimum results, while the 100 variance is the difference between optimum and actual results—the opportunity cost of nonoptimal capacity utilization. That is, by incorrectly estimating the contribution margin of product X_2 and maintaining the ex ante production plan, the firm has foregone obtainable profit of \$100.

If, on the other hand, the c_2 deviation had been avoidable, ex post optimum results would be identical to ex ante results and the opportunity cost variance would be \$600:

$$\begin{aligned} C^aX^a - C^oX^o &= (C^aX^a - C^pX^p) + (C^pX^p - C^oX^o) \\ &= (900 - 900) + (900 - 300) \\ &= 0 + 600 \end{aligned}$$

In either event, however, the cost-volume-mix analysis will produce a \$600 variance because the adjusted budget figure, C^aX^o, ignores the possible shift in optimum results:

$$\begin{aligned} NI^a - NI^o &= (NI^a - NI^b) + (NI^b - NI^o) \\ &= (C^aX^a - C^aX^o) + (C^aX^o - C^oX^o) \\ &= (900 - 900) + (900 - 300) \\ &= 600 \end{aligned}$$

Example 2

As a second variation on the basic example, suppose that everything proceeds according to plan except that product X_1's contribution margin actually was \$4 instead of \$1. Then, $C^o = C^p = (4, 3, 0, 0)$; $(X^a)^T = (X^o)^T = (0, 300, 100, 0)$; $A^a = A^o = A^p$; $b^a = b^o = b^p$; $C^aX^a = C^oX^o = 900$; but $C^pX^p = 1600$.

The final tableau for determination of X^p is:

4	400	1	1	1	0
0	200	0	1	−1	1
		0	1	4	0

with $(X^p)^T = (400, 0, 0, 200)$ and $C^pX^p = 1600$.

Thus, we have an opportunity cost variance of \$700:

$$\begin{aligned} C^aX^a - C^oX^o &= C^aX^a - C^pX^p) + (C^pX^p - C^oX^o) \end{aligned}$$

$$= (900 - 1600) + (1600 - 900)$$
$$= -700 + 700$$

But once again, because it ignores shifts in the original decision, the traditional accounting system does not measure the foregone opportunity. In fact, in this instance, it does not even signal its existence.

$$C^aX^a - C^oX^o = (C^aX^a - C^aX^o) + (C^aX^o - C^oX^o)$$
$$= (900 - 900) + (900 - 900)$$
$$= 0 + 0$$

These two examples should be sufficient to give an understanding of the mechanical aspects of ex post analysis as well as an appreciation of some of the limitations of the traditional accounting system that it is designed to overcome. In a similar fashion, an additional example will give some insight into the significance of the ex post system's major limitation, namely, the joint product term.

Example 3

Assume in our basic example that the following observed values are obtained:

$$C^o = (1.5,\ 3,\ 0,\ 0);$$
$$A^o = \begin{pmatrix} 1/3 & 4/3 & 1 & 0 \\ 1 & 3/2 & 0 & 1 \end{pmatrix};$$
$$b^o = b^a = \begin{pmatrix} 400 \\ 600 \end{pmatrix}; \text{ and } X^o = \begin{bmatrix} 120 \\ 270 \\ 0 \\ 75 \end{bmatrix}$$

with an observed net income of $C^oX^o = 990$. Further assume that the ex post data elements are determined to be: $C^p = C^o$; $b^p = b^a = b^o$; and $A^p = A^o$. That is, we have unavoidable deviations in c_1, $a_{1,\,1}$, $a_{1,\,2}$, and $a_{2,\,2}$.

The final tableau for determination of X^p is:

3	240	0	1	6/5	−2/5
1.5	240	1	0	−9/5	8/5
		0	0	9/10	12/10

with $(X^p)^T = (240,\ 240,\ 0,\ 0)$ and $C^pX^p = 1080$.

Hence,

$$C^aX^a - C^oX^o = (C^aX^a - C^pX^p) + (C^pX^p - C^oX^o)$$
$$= (900 - 1080) + (1080 - 990)$$
$$= -180 + 90$$

Similarly, the traditional accounting system indicates:

$$C^aX^a - C^oX^o = (C^aX^a - C^aX^o) + (C^aX^o - C^oX^o)$$
$$= (900 - 930) + (930 - 990)$$
$$= -30 - 60$$

The real difficulty here is in factoring out the individual opportunity cost significance of each individual deviation—that is, of the deviations in c_1, $a_{1,\,1}$, $a_{1,\,2}$, and $a_{2,\,2}$. By design, no single one of these deviations will alter the ex ante basis, yet their combined effect does—a fact not indicated by the traditional system.

To complete the illustration and give an example of individual price and efficiency computations, further assume that (1) each of the $a_{i,j}$ deviations were labor efficiency variations; (2) the standard wage rates in departments A and B are \$3 and \$6 per unit respectively; (3) unfavorable material price deviations of \$1.5 per unit in X_1 and \$2 per unit in X_2 occurred; and (4) all deviations were unavoidable. Under these assumptions, the tradi-

tional system produces the following individual variances:

(1) Price and efficiency variances: $(C^a - C^o)X^o$	
X_1: Material price variance: 1.5(120)	180 U
Labor use variance (department A) 3(2/3)(120)	240 F
	60 F
X_2: Material price variance: 2(270)	540 U
Labor use variance (department A) 3(1/3)(270)	270 U
Labor use variance (department B) 6(1/2)(270)	810 F
	0
(2) Mix and volume variances $C^a(X^a - X^o)$	
X_1: 1(120)	120 F
X_2: 3(30)	90 U
	30 F

The ex post system, on the other hand, produces the following individual variances:

(1) Forecasting variances: $(C^aX^a - C^pX^p)$	
(a) Basis variances: $C^p(X^a - X^p)$	
X_1: 1.5(240)	360 F
X_2: 3(60)	180 U
	180 F
(b) Price and efficiency variances: $(C^a - C^p)X^a$	
X_1: Material price variance 1.5(0)	0
Labor use variance (department A) 3(2/3)(0)	0
	0
X_2: Material price variance: 2(300)	600 U
Labor use variance (department A) 3(1/3)(300)	300 U
Labor use variance (department B) 6(1/2)(300)	900 F
	0
(2) Opportunity cost variances: $(C^pX^p - C^oX^o)$	
(a) Basis variances: $C^p(X^p - X^o)$	
X_1: 1.5(120)	180 U
X_2: 3(30)	90 F
	90 U
(b) Price and efficiency variances: $(C^p - C^o)X^o$	0

This concludes the description of the mechanical aspects of ex post analysis. The illustrations show how performance and the original program can be simultaneously monitored by focusing on all inputs to the planning model and formally recognizing implied program alterations. The next issue to be resolved is workability of the system.

Results of an Actual Application

These techniques were recently applied in conjunction with a petroleum refinery model in an effort to examine the proposed system's feasibility. The planning model used was a typical linear programming petroleum refinery model. To give an idea of the physical quantities involved, the refinery must produce specified amounts of certain products—such as various gasolines and oils—and these products must meet certain quality specifications. To accomplish this, the refinery has at its disposal certain processing units and a number of raw materials. The problem is to select that combination of raw materials and processing sequences which minimizes the total cost of meeting the stipulated market requirements. In terms of size, the model contains approximately 125 equations in 300 variables with slightly less than 3,000 nonzero elements.

The internal accounting system as-

sociated with the refinery is a typical responsibility center oriented standard cost system. The refinery is structured into divisions, each having departments with individual responsibility centers. Similarly, total cost is segregated into variable and fixed components, where the variable component, in turn, consists of material and refining subcomponents. For each such refinery the firm has a mathematical model which is used for varied economic analyses. One such analysis, a quarterly review of refinery operations was chosen for application.

This quarterly analysis is used mainly for upper management purposes; that is, it is used to gauge the performance of the refinery's management. Actual blended end product production quantities for the quarter are inserted into the model and an adjusted "optimum" budget is determined, reflecting the standard cost of producing the end products actually produced during the quarter. Budgeted, adjusted, and actual results are then compared in an effort to review the particular quarter's performance. Since the resultant variances are designed to provide review statistics for upper management, they are more aggregative than they would be were they designed for use by lower-level operating personnel.

The quarterly accounting system, then, is merely a flexible budgeting arrangement in which actual cost incurred in the production of a set of end products is compared with the standard cost for that set of end products. The standard, in turn, is determined by optimizing the programming model with these specific end-product quantities inserted into the appropriate right-hand elements.

The actual results for a quarter are presented below, where the (unadjusted) ex ante program cost is used to deflate all of the figures:

	Ex Ante (1)	*Adjusted Ex Ante* (2)	*Observed* (3)	*Accounting Variance* (3) − (2)
Crude oil input cost	91.3	92.6	93.7	1.1
Other cost	8.7	8.1	9.2	1.1
Total	100.0	100.7	102.9	2.2

These figures refer to the variable cost of producing a set of certain end-product quantities. The ex ante program represents the originally estimated product requirements, while the adjusted ex ante program represents the standard variable cost of producing the end product quantities actually required and produced.[6] The accounting variances represent the difference between actual and (ex ante) standard variable cost for producing the set of end products actually produced. They are mainly the result of crude usage in excess of that predicted by the model, the 1.1 crude variance, and the use of additional additives necessitated by the inability to operate one of the intermediate processing units at a specified level, the 1.1 other variance.

Beginning with this information provided by the traditional accounting system, the relevant data input elements in the model were re-estimated to reflect the quarter's events. Slightly more than fifty crude yield coefficients were re-estimated to account for the additional crude usage reflected in the crude variance. The other major vari-

[6] An additional difference between the ex ante and ex ante adjusted program is the introduction in the latter of improved catalysts in certain processes, a change in method necessitating a change in the standard.

ance was accounted for in the ex post data triple by deleting the intermediate variable that could not be produced. Then, using the thus determined ex post data triple, (A^p, b^p, C^p), the ex post optimum program and resultant opportunity cost variances were determined. These are presented below.[7]

	Adjusted Ex Ante (1)	*Ex Post* (2)	*Observed* (3)	*Opportunity Cost Variance* (3) − (2)	*Accounting Variance* (3) − (1)
Crude	92.6	92.4	93.7	1.3	1.1
Other	8.1	8.4	9.2	0.8	1.1
Total	100.7	100.8	102.9	2.1	2.2

Generation of the ex post program and resultant opportunity cost variances produces the striking result of two major compensating sets of deviations. Even though the adjusted ex ante crude input estimate was an underestimate, because of yield inaccuracies, introduction of the deletion deviation lowers the optimum crude usage to a level below the original estimate.

Compare this with the information provided by the existing accounting system. This traditional system reports that actual variable cost was 102.9 units while the standard variable cost was 100.7. Additional investigation reveals that 1.1 units of the observed discrepancy is due to inaccurate crude yield coefficients, while the balance is the result of inability to produce a certain intermediate variable—a model error. It does not, however, report what these yield coefficients actually were, nor does it report what the total variable cost should have been.

[7] Discussed more completely in J. S. Demski, "Variance Analysis: An Opportunity Cost Approach with a Linear Programming Application" (Unpublished Ph.D. dissertation, University of Chicago, 1967).

In contrast, the opportunity cost system reflects these deviations in the model, thereby taking into account optimum adjustment to the events actually encountered during the period. Hence, the ex post program cost is the variable cost that should have been incurred during the period. Focusing on the difference between observed and ex post program cost should facilitate review of the period's operations because the standard of comparison has been updated to take into account actual events and optimal adjustment to these events.

Besides indicating what costs should have been, the system also facilitates learning and the taking of remedial action because it provides a framework for assessing the opportunity cost effect of individual deviations. Since the period's events have been reflected in data input and model alterations, the refinery is in a position to examine the effect of each such deviation or set of deviations on the optimal solution (although the jointness difficulties discussed in the previous section are a limitation to any such type of analysis). The crude yield inaccuracies provide an example. The accounting system indicated only that actual crude usage exceeded that predicted by the ex ante adjusted program by 1.1 units. The opportunity cost system, on the other hand, indicates not only what the crude cost should have been but also provides a set of revised crude yield estimates based on the period's operations.

In addition, by taking into account

optimum adjustment to the deviations, the ex post system recognizes interresponsibility center effects. For example, the effect of the inability to operate an internal processing unit at a specified level is to reduce optimum crude usage to an amount below its originally predicted, downward biased amount. Thus, the ex post system provides all of the information supplied by the traditional system plus other information that the accounting system either ignores or obscures.

The ex post system carries this analysis one step further. The deviations are determined, the model and data inputs revised accordingly, and a new program is obtained—a program representing the best that could have been done during the period. This reveals two important considerations obscured or ignored by the accounting system. First, the crude yield inaccuracies appear to be slightly more important in terms of contribution to the total opportunity cost variance of 2.1 units. Because of interdependencies the significance of either set of deviations cannot be uniquely determined. But a close approximation can be developed by observing that had the deletion deviation not occurred, the ex post optimum cost would have been 100.4 units, with 92.8 of crude cost. And the observed cost would have been approximately 101.8 units. That is, the effect of crude coefficient errors appears to be slightly more significant in terms of contribution to the overall opportunity cost variance of 2.1 units. This is potentially valuable information for reviewing the period's performance as well as planning for future periods.

Second, the net effect of these deviations is completely ignored by the accounting system. Predicted crude usage, for example, was 92.6 units while actual usage was 93.7, the result of yield inaccuracies. The implication is that the crude usage was underestimated by the ex ante adjusted program. However, introduction of the deletion deviation so drastically affects the intermediate product mix and quantities that crude usage should have been less than that predicted by the original underestimate.

Hence, by establishing a framework which depicts the best that might have been done, the ex post system provides information superior to that provided by the existing accounting system:

1. By including all planning model inputs in the analysis, the system signals both deviations in performance and deviations in the optimal decision.
2. The effect of any deviation is determined by optimally adjusting all other factors, rather than by assuming their constancy; thus, the deviation's effects on other responsibility centers are determined.
3. It measures the efficiency of the forecasting process by calculating the opportunities foregone as a result of inaccurate data input estimates.

Conclusion

To summarize briefly, the discussion has argued that application of traditional accounting techniques in those situations where well-defined planning models are employed results in generation of control information that ignores possible shifts in the original decision. One possible method of bringing these considerations into the accounting system is to compare routinely what the firm accomplished with what it deems ex post it should have accomplished. This, of course, requires a decision model and the monitoring of all inputs to that model.

For purpose of exposition and application, a linear programming formulation of the planning process was

postulated. Recent application of the proposed approach indicates that this is a feasible approach to generation of control information. And, in fact, the application's results are highly encouraging. First, important deficiencies in the traditional accounting system were observed. Since this traditional model is not an opportunity cost system per se, the most it can be expected to do is to signal the existence of opportunities. In the period analyzed it did signal the existence of deviations, although their source and effect were obscured. A second, and more subjective, result is that application has given every indication that this type of approach is indeed feasible (which should not be confused with an assertion that it is desirable from a cost and value viewpoint). Consequently, it is appropriate to suggest that additional research be done in an effort to examine such issues as the extent to which acounting variances should be aggregated, given a specific decision model, or the extent to which decisions made in response to certain deviations should be considered in the accounting system.

Editorial Comment for Chapter 5

As indicated by the chapter title, the three readings deal with integrated planning and control models. The term "integrated" is used in a dual sense. First, it implies that control is properly related to planning. This is, of course, the central issue in the Demski paper. Second, integration implies a model that is sufficiently comprehensive to include in its scope the major functional areas of a business—production, marketing, and finance. The current state of the art is described in the Khoury and Nelson article. The remaining two readings may be characterized as normative and, perhaps, to some degree, speculative at this point in time. It is encouraging to note, however, that only a few years ago an article advocating simulation for financial planning would also have been labeled "speculative."

Corporate financial models that allow managers to adopt a "try before you buy" approach to decision making have flourished during the past few years. The use of companywide, or integrated, models for strategic planning—such as the Burroughs' model described by Khoury and Nelson—is gaining increasing attention in both academic and industrial circles. It is interesting to note that, while operational level simulation models focusing on physical systems are generally composed of complex equations not fully understood by executives, corporate financial models are based upon planning principles established by top management. Since ultimately the results of a firm's activities must be reported to investors and other interested external parties, it is not surprising that generally the model used is based upon the framework of the financial accounting system.

Time sharing, the simultaneous sharing of a centrally located computer by a number of remotely located user terminals, will in all likelihood stimulate further use of corporate models for strategic planning. Today time-shared computer systems are being applied in such areas as hospital patient monitoring, airline and hotel reservation systems, data gathering and information retrieval, and simple engineering and business problem solving. Their use in strategic planning is in the embryonic stage, but in the very near future[1] computer consoles in executive suites should be an accepted way of life. The Pillsbury Company, an acknowledged leader in advanced information systems, employs time-shared systems in a number of strategic planning areas. Consider two examples recently described by a Pillsbury official.

[1] See "Running the Show with a Keyboard," *Business Week* (July 13, 1968), 76, 78.

One of the uses to which Pillsbury has put time sharing is to analyze a proposed acquisition. A model is developed of the business under consideration for acquisition and then history consisting of sales, costs, cash flow, and profit and loss are entered. Next, the projected sales, costs, market percentage, cash flow, and profit or loss are entered as data, and a projection is run for several years into the future. This model is run by the planning department with a wide variety of inputs and then at an executive committee meeting the terminal is in the room and as questions are raised the variable in question is changed in accordance with the judgment of the various officers. Capital required, cash flow, return on investment, and short- and long-term profit and loss are examined. The model figures are compared with projections made by management of the company being considered for acquisition. Mr. Hanold (President of Pillsbury) and his fellow officers then are in a position to recommend an acquisition to their board and feel confident that they can answer questions and discuss any variety of circumstances. Incidentally, it also puts them in a good bargaining position, when the negotiations with the prospective acquisitions management take place.

• • •

A model that is used extensively is the corporate profit model. Estimates by each division manager of minimum, maximum, and most probable level of profit for their division is input data. The distribution of expected profit for the company as a whole is then produced. The likelihood of any specific deviation can then be tested to observe the effect on total profit. This is run at budget time and throughout year as results occur.[2]

As analytical approaches having both technological and economic feasibility are developed, the relative value of simulation approaches decreases, since they will not necessarily yield optimal solutions. Many areas of business activities do not, however, lend themselves to analytical models at the present state of the art. Khoury and Nelson, for example, chose the simulation approach because the problems associated with a company-wide model are "too complex and have too many variables to be reduced to optimization formulas." Ijiri, Levy, and Lyon, by way of contrast, choose an analytical approach to financial planning.

The Ijiri *et al.* paper, developed in the context of a business game setting, raises the question of the extent to which overall planning is amenable to the use of optimizing techniques. It is true, of course, that linear programming is an optimizing technique, but "this label can be misleading, for it optimizes if, and only if, one assumes that all relevant variables have been properly incorporated and that values of the coefficients are sufficiently accurate" (Rappaport). Let us examine briefly the question of "relevant variables."

It is important to emphasize that there is no argument with the basic approach suggested by Ijiri *et al.;* the issue is its feasibility in an actual industrial application. The question of whether relevant variables have been incorporated in the model hinges upon whether the level of detail is sufficient to include those variables

[2] Clint DeGabrielle, "Why Time-Sharing?" Paper presented at the 1968 Joint National Meeting of the Operations Research Society of America and The Institute of Management Sciences, San Francisco, May 1, 1968.

to which system performance is sensitive. Ordinarily, this requirement would significantly increase the number of variables in a firm with a great number of products, markets, plants, and distribution points. A consideration of a number of the constraints in the Ijiri *et al.* model leads one to conclude that embedded in these constraining equations are predetermined decisions which serve as inputs rather than as outputs of the model. Consider the following range of management decisions: product mix, pricing, allocation of sales and promotional dollars, warranty policy, capital expenditures, manpower planning, plant and warehouse locations, equipment and materials utilization, lease or purchase, research and development strategy, dividend policy, financing policies, organization structure, and diversification and acquisition strategy. Note that such decisions that have already been made determine the nature of the constraining equations. For example, equation (9) places an upper bound on expected sales during the forthcoming period. Presumably this constraint is based upon strategies involving product mix, pricing, advertising, sales effort, warranty, and other factors which influence the level of sales.

It is probably true that in most situations an analytical model the purpose of which is to guide effective overall planning will indeed be "too complex and have too many variables to be reduced to optimization formulas." The inclusion of competitive and other environmental factors further complicates the solution of the model. Whether a model which aims to operate at the strategic level should take a deterministic structure in the face of gross uncertainty must also be seriously considered. Analytical gaps in large planning systems seem to result from a lack of an efficient way of tying local optimization analyses in with the overall planning framework.[3] In the interim the choice will continue to be between corporate simulation models and analytical models when the principal risk is uncertain output due to the aggregation required to make the problem mathematically tractable.

At the outset of this discussion the term "integrated planning and control model" was deemed pervasive in scope; it also implied that the control or performance measurement system must be properly related to the planning system. As Demski points out, where well-defined planning models are used and there has been a shift from original decisions, the traditional variance analysis techniques of cost accountants may be of limited value. This is so because traditional techniques do not distinguish between forecasting variances (that is, the difference between ex ante and ex post results) and opportunity cost variances, which are an approximation of the cost of nonoptimal capacity utilization.

To the extent that Demski's approach is capable of implementation, it possesses great advantages over the usual formats for exception reporting. Measures of a manager's forecasting ability and of his ability to implement decisions efficiently are needed for meaningful performance evaluation. The relative accuracy of

[3] The decomposition principle for linear programs has been suggested as a promising technique in this connection. See William J. Baumol and Tibor Fabian, "Decomposition Pricing for Decentralization and External Economies," *Management Science,* XI (September, 1964).

forecasts is often an instrumental variable in determining how effective and efficient a firm will be in organizing its resources in anticipation of or response to key environmental variables. The approach suggested by Demski may well possess certain positive behavioral consequences in many situations. In a dynamic environmental setting, plans often become obsolete shortly after their development; hence, the aim of control measurements is not to gain results that conform as closely as possible to plans. Nonetheless, conventional variance analysis measurements may indeed motivate some managers in that direction. Another vehicle for minimizing unfavorable variance is, of course, the introduction of bias in the original estimates. The Demski control model which evaluates a manager on *both* his ability to forecast and his skill in utilizing resources would probably be unlikely to induce this type of dysfunctional behavior. At present, this statement is only a hypothesis that needs to be empirically tested. To gain further evidence of the potential for Demski's system, serious investigation of his four underlying assumptions needs to be undertaken.

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6

Information for Production and Marketing Decisions

COST-VOLUME-PROFIT ANALYSIS UNDER CONDITIONS OF UNCERTAINTY

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Traditional cost-volume-profit analysis is frequently used to make choices among alternative courses of action. The usefulness of this analysis is limited because the relative risk of various alternatives is not explicitly accounted for. When risk is introduced into the model, the resulting statement of probabilities with respect to various levels of profits and losses for each alternative should aid the decision maker, once his attitude toward risk has been defined. Illustrations are presented.

Cost-volume-profit analysis is frequently used by management as a basis for choosing among alternatives such decisions as: (1) the sales volume required to attain a given level of profits, and (2) the most profitable combination of products to produce and sell. However, the fact that traditional C-V-P analysis does not include adjustments for risk and uncertainty may, in any given instance, severely limit its usefulness. Some of the limitations can be seen from the following example.

Assume that the firm is considering the introduction of two new products, either of which can be produced by using present facilities. Both products require an increase in annual fixed cost of the same amount, say $400,000. Each product has the same selling price and variable cost per unit, say, $10

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and $8, respectively, and each requires the same amount of capacity. Using these data, the break-even point of either product is 200,000 units. C-V-P analysis helps to establish the break-even volume of each product, but this analysis does not distinguish the relative desirability of the two products for at least two reasons.

The first piece of missing information is the *expected* sales volume of each product. Obviously, if the annual sales of A are expected to be 300,000 units and of B are expected to be 350,000 units, then B is clearly preferred to A so far as the sales expectation is concerned.

However, assume that the expected annual sales of each product is the same—say, 300,000 units. Is it right to conclude that management should be indifferent as far as a choice between A and B is concerned? The answer is *no, unless* each sales expectation is certain. If both sales estimates are subject to uncertainty, the decision process will be improved if the relative risk associated with each product can somehow be brought into the analysis. The discussion which follows suggests some changes which might be made in traditional C-V-P analysis so as to make it a more useful tool in analyzing decision problems under uncertainty.

Some Probability Concepts Related to C-V-P Analysis

In the previous section, it was pointed out that *expected* volume of the annual sales is an important decision variable. Some concepts of probability will be discussed using the example posed earlier.

The four fundamental relationships used in the example were: (1) the selling price per unit; (2) the variable cost per unit; (3) the total fixed cost; and (4) the expected sales volume of each product. In any given decision problem, all four of these factors can be uncertain. However, it may be that, *relative to* the expected sales quantity, the costs and selling prices are quite certain. That is, for analytical purposes, the decision maker may be justified in treating several factors as certainty equivalents. Such a procedure simplifies the analysis and will be followed here as a first approximation. In this section of the paper, sales volume will be treated as the only uncertain quantity. Later, all decision factors in the above example will be treated under conditions of uncertainty.

In the example, sales volume is treated as a *random variable.* A random variable can be thought of as an *unknown quantity.* In this case, the best decision hinges on the value of the random variable, sales volume of each product. One decision approach which allows for uncertainty is to estimate, for each random variable, the likelihood that the random variable will take on various possible values. Such an estimate is called a subjective probability distribution. The decision would then be made by choosing that course of action which has the highest *expected monetary value.* This approach is illustrated in Table 1.

TABLE 1

Probability Distribution for Products A and B

Events (Units Demanded)	*Probability Distribution— (Product A)*	*Probability Distribution— (Product B)*
50,000	—	.1
100,000	.1	.1
200,000	.2	.1
300,000	.4	.2
400,000	.2	.4
500,000	.1	.1
	1.00	1.00

The expected value of the random variables, sales demand for each product, is calculated by weighting the possible conditional values by their respective probabilities. In other words, the expected value is a weighted average. The calculation is given in Table 2.

TABLE 2

Expected Value of Sales Demand for Products A and B

(*1*) *Event*	(*2*) *P*(*A*)	(*1* × *2*)	(*3*) *P*(*B*)	(*1* × *3*)
50,000	—	—	.1	5,000
100,000	.1	10,000	.1	10,000
200,000	.2	40,000	.1	20,000
300,000	.4	120,000	.2	60,000
400,000	.2	80,000	.4	160,000
500,000	.1	50,000	.1	50,000
	1.00		1.00	
Expected Value		300,000 units		305,000 units

Based on an expected value approach, the firm should select product B rather than A. The expected profits of each possible action are as follows:

Product A:
$2(300,000 units) — $400,000
= $200,000
Product B:
$2(305,000 units) — $400,000
= $210,000

Several observations are appropriate at this point. First, the respective probabilities for each product, used in Table 1, add to 1.00. Furthermore, the possible demand levels (events) are assumed to be mutually exclusive and also exhaustive. That is, the listing is done in such a way that no two events can happen simultaneously and any events *not* listed are assumed to have a zero probability of occurring. Herein are three important (basic) concepts of probability analyses.

Secondly, the probability distributions may have been assigned by using historical demand data on similar products, or the weights may be purely subjective in the sense that there is no historical data available. Even if the probability distributions are entirely subjective, this approach still has merit. It allows the estimator to express his uncertainty about the sales estimate. An estimate of sales is necessary to make a decision. Hence, the question is *not* whether an estimate must be made, but simply [what is] the best way to make and express the estimate.

Now, suppose that the expected value of sales for each product is 300,000, as shown in Table 3. In this example, it is easy to see that the firm would *not* be indifferent between products A and B, even though the expected value of sales is 300,000 units in both cases. In the case of product A, for example, there is a .1 chance that sales will be only 100,000 units, and in that case, a loss of $200,000 would be incurred (i.e., $2×100,000 units—$400,000). On the other hand, there is a .3 chance that sales will be above 300,000 units, and if this is the case, higher profits are possible with product A than with product B. Hence, the firm's attitude toward risk becomes im-

TABLE 3

Demand	*P(A)*	*E.V.(A)*	*P(B)*	*E.V.(B)*
100,000 units	.1	10,000	—	—
200,000 units	.2	40,000	—	—
300,000 units	.4	120,000	1.00	300,000
400,000 units	.2	80,000	—	—
500,000 units	.1	50,000	—	—
	1.00		1.00	
Expected Sales Demand		300,000		300,000

portant. The expected value (or the mean of the distribution) is important, but so is the "spread" in the distribution. Typically, the greater the "spread," the greater the risk involved. A quantitative measure of the spread is available in the form of standard deviation of the distribution, and this concept and its application will be refined later in the paper.

The Normal Probability Distribution

The preceding examples were highly simplified and yet the calculations are relatively long and cumbersome. The possible sales volumes were few in number and the probability distribution was discrete, that is, a sales volume of 205,762 units was considered an impossible event. The use of a continuous probability distribution is desirable not only because the calculation will usually be simplified but because the distribution may also be a more realistic description of the uncertainty aspects of the situation. The normal probability distribution will be introduced and used in the following analysis which illustrates the methodology involved. This distribution, although widely used, is not appropriate in all situations. The appropriate distribution depends on the decision problem and should, of course, be selected accordingly.

The normal probability distribution is a smooth, symmetric, continuous, bell-shaped curve as shown in Figure 1. The area under the curve sums to

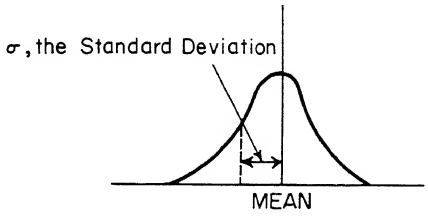


Figure 1
The normal probability distribution

1. The curve reaches a maximum at the mean of the distribution, and one-half the area lies on either side of the mean.

On the horizontal axis are plotted the values of the appropriate unknown quantity or random variable; in the examples used here, the unknown quantity is the sales for the coming periods.

A particular normal probability distribution can be completely determined if its mean and its standard deviation, σ, are known. The standard deviation is a measure of the dispersion of the distribution about its mean. The area under any normal distribution is 1, but one distribution may be "spread out" more than another distribution. For example, in Figure 2, both normal distributions have the same area and the

same mean. However, in one case the σ is 1 and in the other case the σ is greater than 1. The larger the σ, the more spread out is the distribution. It should be noted that the standard deviation is not an area but is a measure of the dispersion of the individual observations about the mean of all the observations—it is a distance.

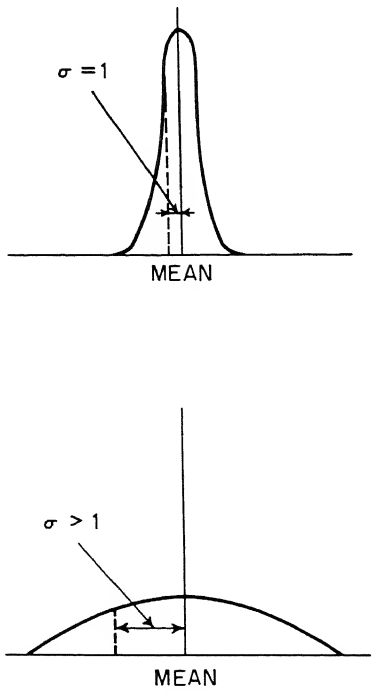


Figure 2

Normal probability distributions with different standard deviations

Since the normal probability distribution is continuous rather than discrete, the probability of an event cannot be read directly from the graph. The unknown quantity must be thought of as being in an interval. Assume, for example, that the mean sales for the coming period is estimated to be 10,000 units and the normal distribution appears as in Figure 3. Given Figure 3, certain probability statements can be made. For example:

1. The probability of the actual sales being between 10,000 and 11,000 units is .20. This is shown by area C. Because of the symmetry of the curve, the probability of the sales being between 9,000 and 10,000 is also .20. This is shown by shaded area B. These probabilities can be given a frequency interpretation. That is, area C indicates that the actual sales will between 10,000 and 11,000 units in about 20 per cent of the cases.
2. The probability of the actual sales being greater than 11,000 units is .30 as shown by area D.
3. The probability of the sales being greater than 9,000 units is .70, the sum of areas B, C, and D.

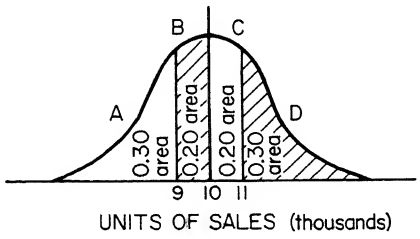


Figure 3

Given a specific normal distribution, it is possible to read probabilities of the type described above directly from a normal probability table.

Another important characteristic of any normal distribution is that approximately .50 of the area lies within $\pm .67$ standard deviations of the mean; about .68 of the area lies within ± 1.0 standard deviations of the mean; .95 of the area lies within ± 1.96 standard deviations of the mean.

As was mentioned above, normal probabilities can be read from a normal probability table. A partial table of normal probabilities is given in Table 4. This table is the "right tail" of the distribution; that is, probabilities of the unknown quantity being greater than X standard deviations from the mean are given in the table. For example, the

probability of the unknown quantity being greater than the mean plus .35σ is .3632. The distribution tabulated is a normal distribution with mean zero and standard deviation of 1. Such a distribution is known as a standard normal distribution. However, any normal distribution can be standardized and hence, with proper adjustment, Table 4 will serve for any normal distribution.

TABLE 4

Area Under the Normal Probability Function

X	*0.00*	*0.05*
.1	.4602	.4404
.3	.3821	.3632
.5	.3085	.2912
.6	.2743	.2578
.7	.2420	.2266
.8	.2119	.1977
.9	.1841	.1711
1.0	.1587	.1469
1.1	.1357	.1251
1.5	.0668	.0606
2.0	.0228	.0202

For example, consider the earlier case where the mean of the distribution is 10,000 units. The distribution was constructed so that the standard deviation is about 2,000 units.[1] To standardize the distribution, use the following formula, where X is the number of standard deviations from the mean:

$$X = \frac{\text{Actual sales} - \text{mean sales}}{\text{Standard deviation of the distribution}}.$$

[1] To see why this normal distribution has a standard deviation of 2,000 units, remember that the probability of sales being greater than 11,000 units is .30. Now examine Table 4, and it can be seen that the probability of a random variable being greater than .5 standard deviations from the mean is .3085. Hence, 1,000 units is about the same as $\frac{1}{2}$ standard deviations. So, 2,000 units is about 1 standard deviation.

To calculate the probability of the sales being greater than 11,000 units, first standardize the distribution and then use the table.

$$X = \frac{11{,}000 - 10{,}000}{2{,}000} = .50 \text{ standard deviations.}$$

The probability of being greater than .50 standard deviations from the mean, according to Table 4, is .3085. This same approximate result is shown by Figure 3, that is, area D is .30.

The Normal Distribution Used in C-V-P Analysis

The normal distribution will now be used in a C-V-P analysis problem, assuming that sales quantity is a random variable. Assume that the per-unit selling price is $3,000, the fixed cost is $5,800,000, and the variable cost per unit is $1,750. Break-even sales (in units) is calculated as follows:

$$S_B = \frac{\$5{,}800{,}000}{\$3{,}000 - \$1{,}750} = 4{,}640 \text{ units.}$$

Furthermore, suppose that the sales manager estimates that the mean expected sales volume is 5,000 units and that it is equally likely that actual sales will be greater or less than the mean of 5,000 units. Furthermore, assume that the sales manager feels that there is roughly a $\frac{2}{3}$ (i.e., .667) chance that the actual sales will be within 400 units of the mean. These subjective estimates can be expressed by using a normal distribution with mean $E(Q) = 5{,}000$ units and standard deviation $\sigma_q = 400$ units. The reason that σ_q is about 400 units is that, as mentioned earlier, about $\frac{2}{3}$ of the area under the normal curve (actually .68) lies within 1 standard deviation of the mean. The probability distribution is shown in Figure 4.

The horizontal axis of Figure 4

denotes sales quantity. The probability of an actual sales event taking place is given by the area under the probability distribution. For example, the probability that the sales quantity will exceed 4,640 units (the break-even point) is the shaded area under the probability distribution (the probability of actual sales exceeding 4,640 units).

The probability distribution of Figure 4 can be superimposed on the profit portion of the traditional C-V-P; this is done in Figure 5. The values for

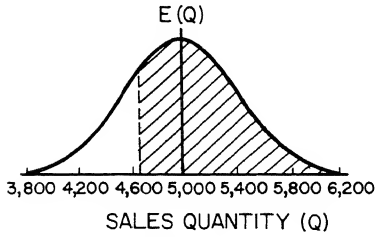


Figure 4

price, fixed costs, and variable costs are presumed to be known with certainty. Expected profit is given by:

$$E(Z) = E(Q)\ (P\text{-}V) - F$$
$$= \$450{,}000,$$

$E(Z)$ = Expected Profit
$E(Q)$ = Expected Sales
P = Price
V = Variable Cost
F = Fixed Cost.

The standard deviation of the profit (σ_z) is:

$$\sigma_z = \sigma_q \times \$1{,}250 \text{ contribution per unit}$$
$$= 400 \text{ units} \times \$1{,}250 = \$500{,}000.$$

Since profits are directly related to the volume of sales, and since it is the level of profits which is often the concern of management, it may be desirable to separate the information in Figure 5 which relates to profit. Figure 6 is a graphical illustration of the relationship between profit level and the probability distribution of the profit level. A number of important relationships can now be obtained in probabilistic terms. Since the probability distribution of sales quantity is normal with a mean of 5,000 units and a standard deviation of 400 units, the proba-

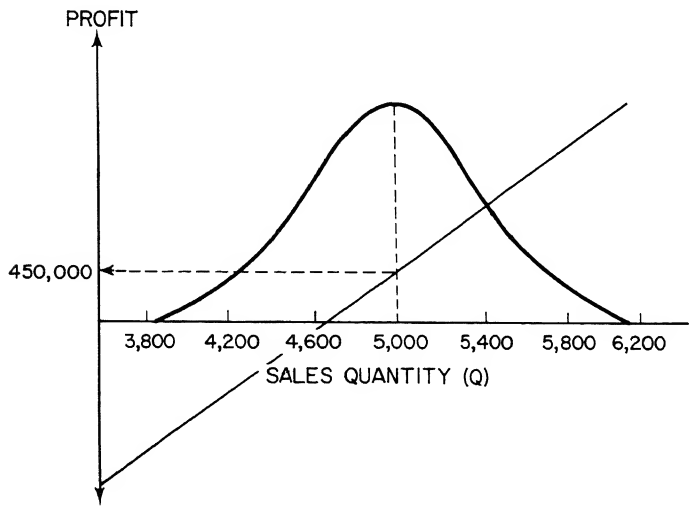


Figure 5

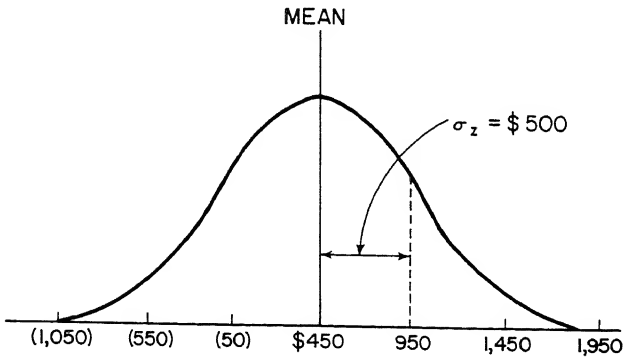


Figure 6

bility distribution of profits will also be normal with a mean, as shown earlier, of $450,000 and a standard deviation of $500,000.

Using the probability distribution shown in Figure 6, the following probabilities can be calculated (using Table 4).

1. The probability of at least breaking even: This is the probability of profits being greater than zero. and can be calculated by summing the area under the distribution to the right of zero profits. This probability can be calculated as 1—(the probability of profits being less than zero). Since the distribution is symmetric, Table 4 can be used to read left tail as well as right tail probabilities. Zero profits fall .9 standard deviations to the left of the mean

$$\left(\text{ie., } \frac{\$450 - 0}{\$500} = .9\right)$$

Hence, the probability of profits being less than zero is:

$P(\text{Profits} < .9\sigma \text{ from the mean}) = .184.$

Therefore

$P(\text{Profits} > 0) = 1 - .184 = .816.$

2. The probability of profits being greater than $200,000.

$$P(\text{Profits} > \$200{,}000) = 1 - P\left(\text{Profits} < \frac{450 - 200}{500}\sigma \text{ from the mean}\right)$$

$$= 1 - P(\text{Profits} < .5\sigma \text{ from the mean})$$

$$= 1 - .3085 = .692.$$

3. The probability of the loss being greater than $300,000.

$$P(\text{Loss} > \$300{,}000) = P\left(\text{Loss} > \frac{450 - (-300)}{500}, \text{ or } 1.5\sigma \text{ from the mean}\right)$$

$P = .067.$

The question of how the above information can be used now arises. The manager, in choosing between this product and other products or other lines of activity, can probably improve his decision by considering the risk involved. He knows that the break-even sales is at a level of 4,640 units. He knows that the expected sales are 5,000 units which would yield a profit of $450,000. Surely, he would benefit from knowing that:

1. The probability of at least reaching break-even sales is .816.

2. The probability of making at least $200,000 profit is .692.
3. The probability of making at least $450,000 profit is .50.
4. The probability of incurring losses, i.e., not achieving the break-even sales volume, is (1 − .816, or .184).
5. The probability of incurring a $300,000 or greater loss is .067.

If the manager is comparing this product with other products, probability analysis combined with C-V-P allows a comparison of the risk involved in each product, as well as a comparison of relative break-even points and expected profits. Given the firm's attitude toward and willingness to assume risk (of losses as well as high profits), the decision of choosing among alternatives should be facilitated by the above analysis.

Several Relevant Factors Probabilistic

It is evident from the above discussion that profit, Z, is a function of the quantity of sales in units (Q); the unit selling price (P); the fixed cost (F); and the variable cost (V). Up to this point P, F, and V were considered only as given constants, so that profit was variable only as a function of changes in sales quantity. In the following discussion, P, F, and V will be treated in a manner similar to Q, i.e., as random variables whose probability distribution is known.[2] Continuing the example from the preceding section, let

Variable
Sales Quantity (Q)
Selling Price (P)
Fixed Costs (F)
Variable Costs (V)

Expectation (Mean)

$E(Q') = 5{,}000$ units
$E(P') = \$3{,}000^2$
$E(F') = \$5{,}800{,}000^2$
$E(V') = \$1{,}750^2$

Standard Deviation

$\sigma_{Q'} = 400$ units
$\sigma_{P'} = \$50^2$
$\sigma_{F'} = \$100{,}000^2$
$\sigma_{V'} = \$75^2$

For purposes of illustration, the random variables will be assumed to be independent, so that no correlation exists between events of the different random variables.[3] In this case, the expected profit $E(Z')$ and the related standard deviation $\sigma_{Z'}$ can be calculated as follows[4]:

$$E(Z') = E(Q')[E(P' - E(V')] - E(F') = \$450{,}000.$$
$$\sigma_{Z'} = \$681{,}500.$$

Note that when factors other than sales are treated as random variables, the expected profit is still $450,000 as in the previous cases. However, the profit's risk as measured by the standard deviation is increased from $500,000 to $681,500. The reason for this is that the variability in all of the components

[2] The mean and standard deviation for P, F, and V can be established by using the same method described earlier. That is, the sales manager may estimate a mean selling price of $3,000 per unit and, given the above information, he should feel that there is roughly a ⅔ probability tht the actual sales price per unit will be within $50 of this mean estimate.

[3] This assumption is made to facilitate computation in the example. Where correlation among variables is present the computational procedure must take into account the values of the respective covariances.

[4] For the case of independent variables given here, $\sigma_{Z'}$ is the solution value in the equation:

$$\sigma_Z = \sqrt{[\sigma_{Q^2}(\sigma_{P^2} + \sigma_{V^2}) + E(Q')^2(\sigma_{P^2} + \sigma_{V^2}) + [E(P') - E(V')]^2 \sigma_{Q^2} + \sigma_{F^2}]}$$

(i.e., sales price, cost, etc.) will add to the variability in the profit. Is this change in the standard deviation significant? The significance of the change is a value judgment based on a comparison of various probabilistic measures and on the firm's attitude toward risk. Using a normal distribution, Table 5 compares expected profits, standard deviations of profits, and select probabilistic measures for three hypothetical products.

In all three situations, the proposed products have the same break-even quantity—4,640 units. The first case is the first example discussed where sales quantity is the only random variable. The second case is the one just discussed; that is, all factors are probabilistic. In the third case, the assumed product has the same expected values for selling price, variable cost, fixed cost, and sales volume, but the standard deviations on each of these random variables have been increased to $\sigma_{Q''} = 600$ (instead of 400 units); $\sigma_{P''} = \$125$ (instead of \$50); $\sigma_{F''} = \$200{,}000$ (instead of \$100,000); and $\sigma_{V''} = \$150$ (instead of \$75).

Table 5 shows the relative "risk" involved in the three new products which have been proposed. The chances of at least breaking even are greatest with product 1. However, even though the standard deviation of the profit on product 3 is over twice that of product 1, the probability of breaking-even on product 3 is only .17 lower than product 1. Likewise, the probability of earning at least \$250,000 profit is higher for product 1 (which has the lowest σ) than for the other two products.

However, note that the probability of earning profits above the expected value of \$450,000 (for each product) is *greater* for products 2 and 3 than for 1. If the firm is willing to assume some risk, the chances of high profits are improved with product 3, rather than with 2 and 1. To offset this, however, the chance of loss is also greatest with product 3. This is to be expected, since product 3 has the highest standard deviation (variability) as far as profit is concerned.

The best alternative cannot be chosen without some statement of the firm's attitude toward risk. However, given a certain attitude, the proper choice should be facilitated by using probability information of the type given in

TABLE 5

Comparison of Expected Profits, Standard Deviations of Profits, and Probabilistic Measures*

	Products		
	(*1*)	(*2*)	(*3*)
Expected profit	\$450,000	\$450,000	\$ 450,000
Standard deviation of profit	\$500,000	\$681,500	\$1,253,000
The probability of:			
(a) at least breaking even	.816	.745	.641
(b) profit at least +\$250,000	.655	.615	.564
(c) profit at least +\$600,000	.382	.413	.456
(d) loss greater than \$300,000	.067	.136	.274

* Note: The above probabilities, in some cases, cannot be read from Table 4. However, all probabilities come from a more complete version of Table 4.

Table 5. As an example, suppose that the firm's position is such that any loss at all may have an adverse affect on its ability to stay in business. Some probability criteria can, perhaps, be established in order to screen proposals for new products. If, for example, the top management feels that any project which is acceptable must have no greater than a .30 probability of incurring a loss, then projects 1 or 2 would be acceptable but project 3 would not.

On the other hand, the firm's attitude toward risk may be such that the possibility of high profit is attractive, provided the probability of losses can be reasonably controlled. In this case, it may be possible to set a range within which acceptable projects must fall. For example, suppose that the firm is willing to accept projects where the probability of profits being greater than $600,000 is at least .40, provided that the probability of a loss being greater than $300,000 does not exceed .15. In this case, project 2 would be acceptable, but project 3 would not. Given statements of attitude toward risk of this nature, it seems that a probability dimension added to C-V-P analysis would be useful.

Summary and Conclusion

In many cases, the choice among alternatives is facilitated greatly by C-V-P analysis. However, traditional C-V-P analysis does not take account of the relative risk of various alternatives. The interaction of costs, selling prices, and volume is important in summarizing the effect of various alternatives on the profits of the firm. The techniques discussed in this paper preserve the traditional analysis but also add another dimension—that is, risk is brought in as another important decision factor. The statement of probabilities with respect to various levels of profits and losses for each alternative should aid the decision maker once his attitude toward risk has been defined.

PERT/COST: THE CHALLENGE

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PERT/Cost represents an expansion of PERT/Time and can be used to obtain the optimum mix of project time and cost. PERT/Cost expense estimates are activity-oriented and thus cross organizational structures and time periods to define the task. PERT/Cost assists project managers by assigning costs in sufficient detail for planning schedules and costs, evaluating schedule and cost performance, and predicting and controlling costs during the operating phase of the project. Some of the basic problems associated with implementing PERT/Cost systems are enumerated.

Each day that passes sees the growth of new management planning and control tools. Many of these new tools leave the accountant with the unhappy feeling that he should be participating in their use but that he lacks the orientation for active involvement. The desire of the accountant to become involved with these tools is evident from the growth of "management planning and control" chapters in textbooks and the numerous articles dealing with the managerial aspects of accounting output.

One of the newest tools, if evidenced by current publications, is Program Evaluation and Review Technique (PERT). Recently, there have been many discussions, publications, and applications of this technique. PERT's acceptance has been widespread. The accountant must become involved with PERT if he accepts the challenge of Norton Bedford that "the accounting profession has the potential to become one of the great professions if it will accept all phases of measurement and communication of economic data as within its province."[1]

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[1] John L. Carey, *The Accounting Profession: Where Is It Headed?* (New York: American Institute of CPA's, 1962), p. 94.

The principal motivating factor in PERT development has been the growth of the concept of systems management within the military services. With programs of unprecedented size, complexity, and breadth, an integrating device has become mandatory. In addition, time is of the essence in weapons system design and development. PERT/Time has been a powerful tool in the kit of managers for planning, coordinating, and integrating these weapon systems.

The culmination of PERT/Time is the network. This network is a pictorial representation of the events and activities that lead to completion of the end objectives. The events represent the beginning and/or ending of activities. An *event* is a specific accomplishment, or milestone. The *activities* represent things that must be done in going from one event to another. The activity is the time-consuming task. The activities are related to their order of precedence in accomplishing the events. The end result is a network depicting a well-thought-out plan. After the flow of activities and events is mapped, schedule timing can be superimposed. When completion times are included on the activities, the critical path (longest time path) can be determined.

At this point the manager has a tool which needs no further justification. The network presents a clear picture of

all the activities and events that must be accomplished before the end objective can be attained. The individuals with responsibility for accomplishment will have discussed all of the relationships, potential drawbacks, and completeness of the plan. When times are imposed upon the plan, the problems of a timely completion are apparent. The activities affecting a timely completion and the schedule's effect on workloads are laid bare for scrutiny. When actual times become available, the updated estimates provide a dynamic control tool to anticipate adverse results. There can be little question that PERT/Time is a tool which, when applied with common sense and vigor, represents a "breakthrough" in management planning and control of the valuable resource of time.

Time-Cost Mix

PERT/Cost is, in reality, an expansion of PERT/Time. With times indicated on the network, it becomes possible to consider alternative plans of action. As the network is being developed, time options are presented which can be considered. Techniques of system simulation can be employed to ensure that the activities and events will lead to the best climax. The next logical step, with time options available, is to obtain the optimum mix of time and cost. This has led to the attempt to assign costs to the activities on the network. An additional advantage when costs have been assigned to the network for time-cost options is that they can be summed for total cost planning and control.

The development of a system for cost accumulation synchronized with the PERT/Time network must be founded upon objectives consistent with the responsibility of management. In program management, the manager is faced with a twofold job. He is charged with the financial planning and control of his firm's resources, while at the same time he is committed to delivery of the end items with a minimum of cost incurrence to the customer.

This was recognized by the developers of PERT/Cost, NASA and the Department of Defense, when they visualized it as a three-part system.[2] Basic PERT/Cost is intended to assist the project managers by assigning costs to the working levels in the detail needed for planning schedules and costs, evaluating schedule and cost performance, and predicting and controlling costs during the operating phase of the program. In addition, there are two supplemental procedures. The Time-Cost Option Procedure displays alternative Time-Cost plans for accomplishing project objectives. The Resource Allocation Procedure determines the lowest cost allocation of resources among individual project tasks to meet the specified project duration. The basic system is to provide total financial planning and control by functional responsibility, while the two supplements are to achieve minimum cost incurrence.

The concept of cost predetermination for planning and control is not new to the accountant. The entire function of budgeting is predicated upon predetermination. Comprehensive budgeting relates income budgets, covering revenues and expenses, to the financial goals of the firm. The expense budgets lead to financial planning and control via projected income; while at the same time, the flexible budget and the expense forecasts serve as tools for decision making by relating costs to volume.

[2] *DOD and NASA Guide: PERT/Cost,* Published by the Office of the Secretary of Defense and the National Aeronautics and Space Administration, June, 1962.

PERT/Cost estimates are a new way of looking at the expense budgets. If properly conceived, they can become an integral part of the comprehensive budget program. Yet they differ from conventional expenses budgeting in certain respects. From the financial planning and control viewpoint, the PERT/Cost estimates are not concerned with accounting periods. PERT/Cost is activity oriented. There is a cutting across of organizational structures and time periods to define "things to be accomplished." The focal point of cost accumulation shifts from the department to the project work package. The annual budget is bypassed to encompass an end item accomplishment. From the detailed decision-making viewpoint, where the flexible budget normally uses volume as the factor of variability, PERT/Cost attempts to use activity time. These two differences will now be examined in more detail.

Cost Framework

The establishment of a PERT/Cost system begins by developing a framework for gathering cost data and preparing the schedule for all activity levels. The project is defined, then broken down into end item subdivisions, and then into work packages which are assignable to front-line supervision. The integration of the work packages is accomplished through the conventional PERT/Time network. When the interrelationships and time paths have been plotted, the responsible operating and managerial personnel develop cost estimates for each work package.

It is important that both cost and time be planned and controlled from a common framework. From such a framework, the managers can obtain an accurate picture of progress and at the same time appraise realistically the consequences of alternative courses of action. The PERT/Time network is this common framework. This imposes upon the network developers the responsibility of carefully defining the activities so that they can represent cost centers as well as the areas of work effort.

The identification of the project objectives in terms of end items is the starting point for network design to be used with PERT/Cost. By using a top-down approach in the development of the network, the total project is fully planned and all components of the plan are included. Standard units for the breakdown of work below the project level are system, subsystem, task, and subtasks. The work breakdown continues to successively lower levels until the size, complexity, and dollar value of each level is a workable planning and control unit. These subdivisions are end item subdivisions representing horizontal segments of the total project. The final step would be to divide each of these end item subdivisions into the tasks that must be done to complete them, i.e., design, manufacturing testing, and so forth. This concept is demonstrated in Figure 1.[3] It is this project work breakdown that serves as the input data to the network.

The theoretical optimum level of cost accumulation would be the functional level of each of the end item subdivisions. For example, a cost account would be established for mechanical engineering of the instrumentation, one for manufacturing, and one for testing. The PERT/Cost estimates would then be made for manpower, material, and overhead charges for each of these work packages. It is obvious that a cost accounting system broken down into such intricate detail would comprise numerous accounts. The prag-

[3] *DOD and NASA Guide: PERT/Cost,* p. 28.

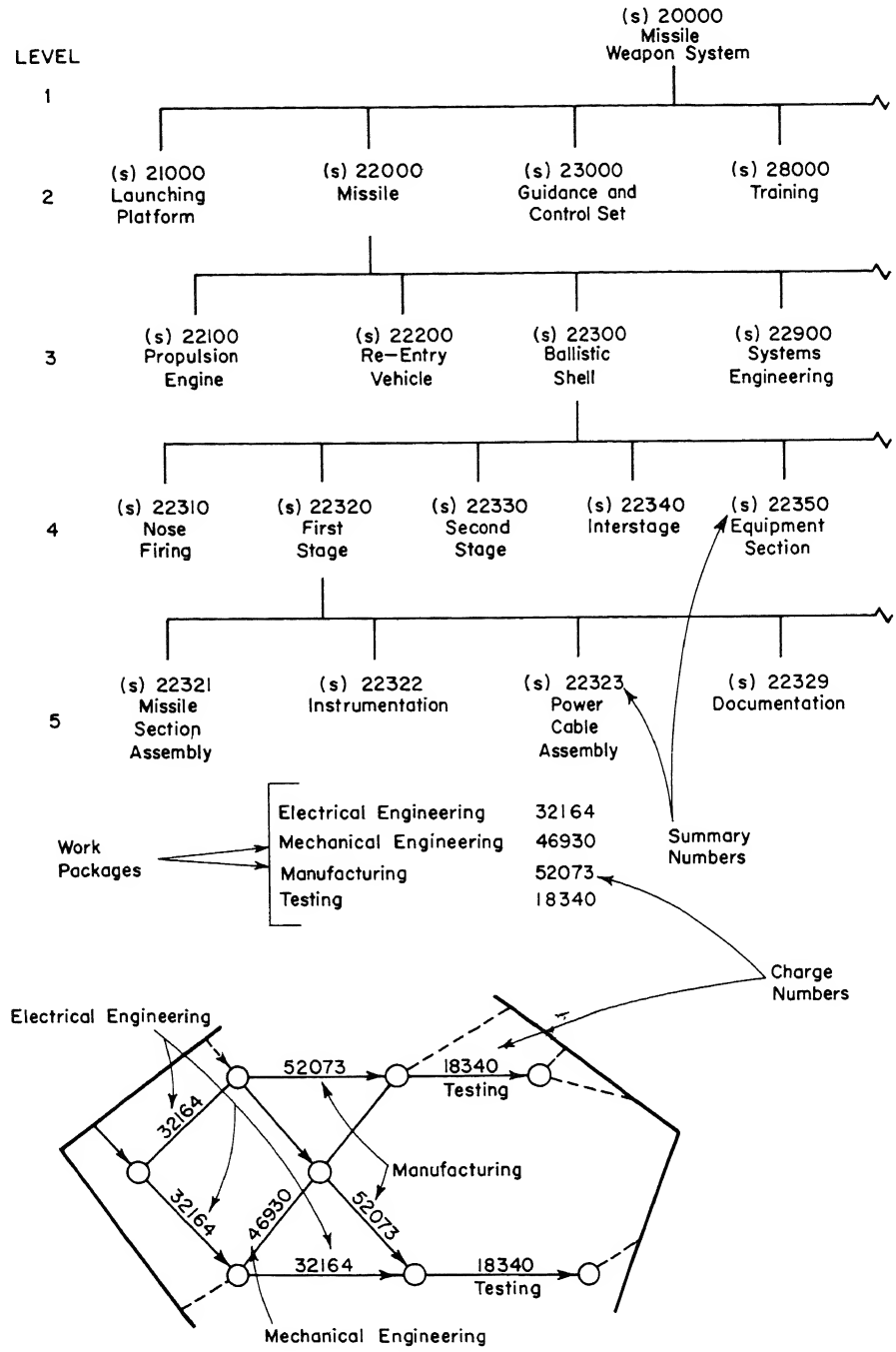


Figure 1

Simplified example of a work breakdown structure and account code structure

matic number of account subdivisions will naturally depend upon the detail needed for planning and control, the dollar value of the subdivisions, the activity time on the network, and the machine and personnel capacity available. A practical compromise is often necessary.

PERT/Cost Cost Development

Once the network has been established, based upon the project work breakdown, costs can be estimated. If the breakdown has been made satisfactorily, it will serve as both an estimating and actual cost accumulation vehicle. The proper implementation of PERT/Cost, like budgeting, must rest upon active participation by the responsible executives. This was recognized by the NASA/DOD PERT/Cost Guide when it was recommended that the operating and management personnel develop the cost estimates for each work package.[4] As with budgeting, any accounting work during the estimation period would be of coordinating nature.

The development of the cost estimates must rest upon a sound philosophical basis consistent with management needs. Presently there are four approaches to developing the cost estimates:

1. A single cost estimate of expected actual cost
2. Three cost estimates combined by formula into expected cost.
3. Optimum time-cost curves (used in construction industries and by NASA/DOD Resource Allocation Procedure Supplement)
4. Three separate cost estimates (used in the NASA/DOD Time-Cost Option Procedure Supplement)

[4] *DOD and NASA Guide: PERT/Cost,* pp. 109–13.

Each of these theories of PERT/Cost estimating has as its goal the assigning of the best cost estimates possible to the network. Yet each offers the manager separate, distinct planning capabilities.

A single cost estimate of expected actual cost is based upon the summation of the cost elements. These estimates are first made by determining the manpower, material, and other resources required to complete each work package. The estimates for the direct costs applicable to the network activities are expressed in terms of expected dollar expenditures. Indirect costs may then be allocated to the individual work package or added to the total cost of the project.

The three-cost-estimate approach has as its goal the determination of the "expected cost." The advantage of the three cost estimate over the single cost estimate is that the result is subject to probability analysis. The formula combines an optimistic, most likely, and pessimistic cost estimate. The mean cost for each activity is calculated by the formula:

$$C_e = \frac{C_P + 4C_L + C_O}{6}$$

where C_P is the pessimistic estimate, C_L is the most likely cost, and C_O the optimistic estimate. The standard deviation of the cost distribution can insert probability into the analysis. With this expected cost, the manager cannot necessarily assume that he has the optimum cost-time mix. However, if the cost estimates are realistic, the probabilities of achieving the expected cost can be used for project negotiations.

A third approach to cost estimates is the optimum time-cost curve concept. This is differential costing with time as the factor of variability. The intention of this approach is to optimize

time and costs by using optimum estimated costs. It assumes there is a direct relationship between time and costs on any activity. This relationship can be expressed by a continuous curve. If a cost curve can be developed similar to Figure 2, many insights can be

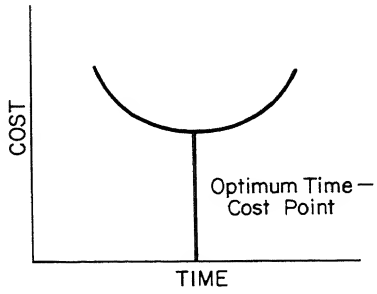


Figure 2

gained. Network schedules can be modified to obtain the lowest cost commensurate with the customer's delivery desires. Other questions can also be anticipated—questions such as: How long will completion take with a fixed budget? What will the costs be to complete the project within a given time period? In theory this concept is undoubtedly superior to either the one or three formula estimates, but without complete historical cost data the development of this curve is impractical.

Because the development of continuous time-cost curves for all activities is extremely difficult, if not practically impossible, the Resource Allocation Supplement to PERT/Cost was developed. This supplement is a variation of continuous time-cost curves which can be used in planning a small group of *significant* activities representing only a minor portion of the overall project. This method is also based upon the concept that activities are subject to time-cost trade-offs. The steps of this procedure are shown in the diagrams in Figure 4.

Another alternate to overcome the practical problem of the continuous cost curve is a linear function based upon two time-cost relationships. The cost and time expenditures are forecast for two conditions: normal and crash. The normal point is the minimum activity cost and the corresponding time. The crash point is defined as the minimum possible time to perform the activity and the related cost. A linear function is assumed to exist between these points. Figure 3 shows this graphically. This method is similar to the high-low point

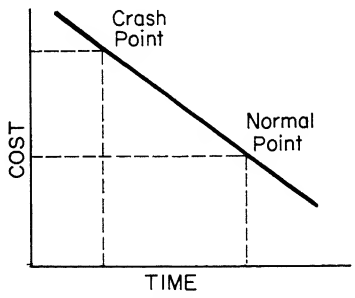


Figure 3

method of fixed and variable cost determination and suffers from the same type of criticism.[5]

The problems of realistic estimates, dis-

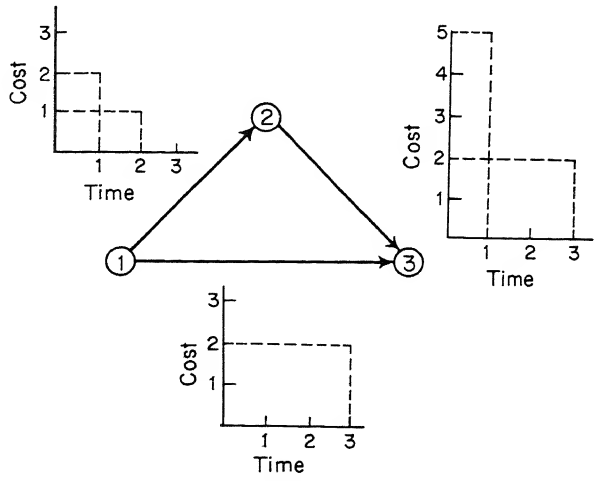
[5] Glenn Welsch, *Budgeting: Profit Planning and Control* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1957), pp. 173–74.

Figure 4

A summary of the resource allocation procedure. In the Resource Allocation Procedure, we can determine how to accomplish a project by a specified date at minimum cost. The critical path here is the path from Event 1 to Event 2, and from Event 2 to Event 3, since this will require five days at absolute minimum costs. But the Directed Data for completing the project is four days from its beginning. Thus, from the time-cost chart, we find that we can cut the time between Events 1 and 2 to one day, but we double the cost of this activity. Since shortening the time of the second step in the critical path would cost more, however, we choose to reduce time of the first step to one day.

Step 1: Construct Network

Step 2: Obtain Alternative Time-Cost Estimates for Each Activity

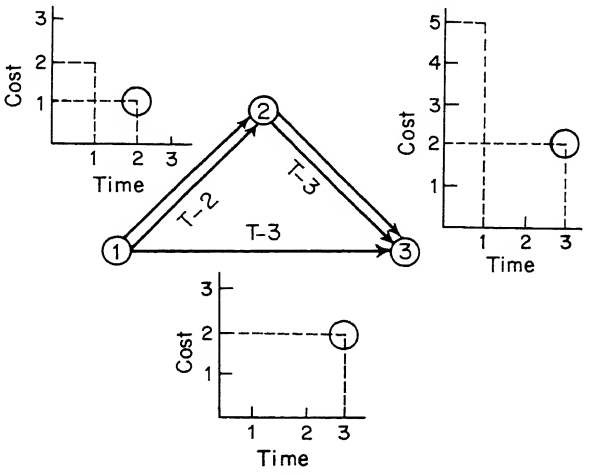


Step 3: Select the Lowest Cost Alternatives for Each Activity

Step 4: Calculate Critical Path and Compare with the Directed Date.

Critical Path is 5

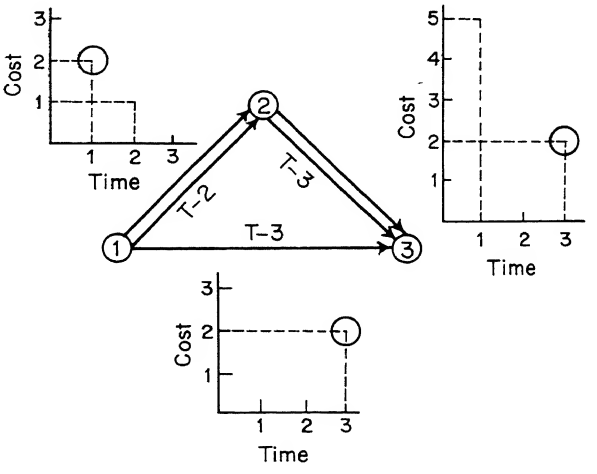
Directed Date is 4

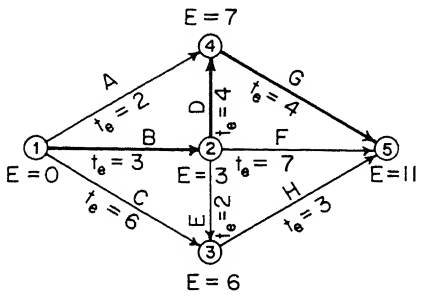


Step 5: Adjust Critical Path to Agree with Directed Date Using Lowest Costs.

Critical Path is 4

Directed Date is 4





Where:
t_e is the estimated time per activity

E is the expected completion time of the event

Figure 5

An illustration of normal-crash procedure. The critical path of this network is eleven days. To accelerate the program one day, activities B, G, or D must be condensed one day. Based upon cost curves computed on a normal-crash basis, the table of costs below is available.

	Normal		*Crash*		*Accelera-*
Activ-					*tion Cost*
ity	*Days*	*Cost*	*Days*	*Cost*	*per Day*
A	2	80	1	130	50
B	3	70	1	190	60
C	6	110	5	135	25
D	4	60	3	100	40
E	2	90	1	100	10
F	7	85	6	115	30
G	4	105	3	175	70
H	3	50	2	70	20
Totals		650		1015	

Since Activity D costs $40 to accelerate, whereas Activity G costs $70 and Activity B, $120, accelerating Activity D is least expensive. The total cost of completing the program in ten days is $690 ($650 + $40). By compressing the project one day, Activity F enters the critical path. To accelerate the program to nine days the following activities could be reduced: G and F at a total cost of $100 or B at a cost of $60. Therefore, for the reduction to nine days the cost would be $750 ($650 + $40 + $60).

cretionary costs, stair-stepped cost functions, incorrect correlation between time and cost, and external factors are continually present. It is justifiable due to its relative simplicity when the element of nonpredictable error can be permitted. A simplified, but typical usage is shown in Figure 5.

The NASA/DOD PERT/Cost Guide presents a time-cost option (called the Time-Cost Option Procedure Supplement) based upon three time estimates. The single estimate of expected cost and the three-cost-estimate formula methods do not indicate whether there may be a substantially more efficient alternative plan. The continuous cost curve concept provides these data[6] but requires considerable sophistication in cost analysis, or else, considerable supposition. The time-cost supplement recognizes that a single estimate will normally be used for contract proposals and that additional data are needed to provide information as to the amount of time that might be saved by spending more money or the amount of money that could be saved by extending the contract time. The three time estimates used are:

1. *The most efficient plan.* This is the network plan that will meet the technical requirements of the project utilizing the most efficient use of present resources. This is the plan that would be chosen without budget and time constraints.
2. *The directed date plan.* This is the network plan developed to meet the technical requirements of the project by the specified completion date.
3. *The shortest time plan.* This is the network plan that will meet the technical requirements of the project in the shortest possible time.

Since the desired plan is the most efficient plan, any study should begin there. This most efficient plan must then be modified to achieve the project's objectives by the specified date. The most efficient plan when altered

[6] See Figure 2.

to attain the desired delivery date becomes the directed date plan. The directed date plan is then revised to obtain the shortest time plan. The work packages that have not changed in evolving the alternate plans will utilize cost estimates for the most efficient plan. New cost estimates will be necessary only on those work packages that are expected to increase or decrease because of the modifications. With three estimates on these work packages, the customer is apprised of the impact of his decisions during negotiations. Once the customer has made his decision, the appropriate cost estimate can be assigned to the network.

These cost estimating techniques represent the current approaches to computing forecasted costs. When coupled with a sound approach to determining the project work breakdown, forward planning is definitely facilitated. To this point PERT/Cost is a planning tool, but the loop between planning and control is not closed. For control there must be comparisons of actual cost expenditures with those estimated during the planning stage. The accountant must play an active role when the loop is closed between the planning and control phases. The generation of feedback data consistent with the planning stage calls for a chart of accounts correlated to the PERT network.

The PERT/Cost Challenge

The accountant is charged by management and society with providing financial information for all levels of decision making. If the accountant is to serve the managers effectively, he will have to broaden his influence beyond the confines of historical data to include all areas of the firm and the future. PERT/Cost offers him one challenge in this direction. It can be seen that if PERT/Cost can be coordinated with PERT/Time, the manager has an excellent tool for project planning and control. In addition to financial reporting both on the total cost level and the individual manager's level, it offers distinct opportunities for decision making during both the planning and control phases.

The discussions here might lead one to believe that PERT/Cost offers no problems. Unfortunately, this is not the case. Despite the potential, there are basic problems. An enumeration of some of these problems would include:

1. PERT/Cost for decision making in optimizing costs requires a sophistication of cost analysis that is not possessed by some firms.
2. There is a lack of historical information for assigning costs to networks since the concept is new.
3. There is difficulty in making project costs compatible with fiscal practices.
4. The problems of overhead charges, joint costs, and incompatibility of the organizational cost flow with the functional flow are numerous.
5. There is a problem of reconciling the "jobs" that are using PERT/Cost with those that aren't for fiscal reporting.
6. The personnel and machine capabilities are not always available.
7. Cost accumulation for financial stewardship reports can conflict with the cost centers for PERT/Cost and can therefore create redundant systems.
8. The conversion of project oriented costs to mesh with annual budget concepts requires additional analysis.

If the problems associated with PERT/Cost can be resolved, PERT with COST could be considered a major breakthrough as was PERT with TIME. The majority of the potential problem areas with PERT/Cost lie in the controller's department. These difficulties present a very real challenge to the controller. PERT/Cost is putting the adaptability of the accountant to the test.

A DESIGN FOR THE FIRM'S MARKETING NERVE CENTER

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NORTHWESTERN UNIVERSITY

In this era when there are more markets and products than ever before, competitors operate swiftly and deftly, and law, technology, economics, and culture are undergoing rapid changes, marketing information systems are generally inadequate. Unmanaged information systems experience a high frequency of information disappearance, delay, and distortion. A blueprint for a marketing nerve center that promises to improve the accuracy, timeliness, and comprehensiveness of executive marketing information services is presented in this reading.

As company operations expand in size and complexity, company executives grow further removed from firsthand contact with the scenes of marketing action. They have to rely increasingly on secondhand information for their picture of what is happening in the marketplace, and, on the basis of highly fragmented and typically tenuous information, must make decisions that have profound consequences. The company's effectiveness in the marketplace is increasingly at the mercy of the executive's marketing information.

It is hard to find executives who are satisfied with the quality of their marketing information. Their complaints fall into a number of categories:

1. There is too much marketing information of the wrong kind and not enough of the right kind.
2. Marketing information is so dispersed throughout the company that a great effort is usually necessary to locate simple facts.
3. Important information is sometimes suppressed by other executives or subordinates, for personal reasons.
4. Important information often arrives too late to be useful.
5. Information often arrives in a form that leaves no idea of its accuracy, and there is no one to turn to for confirmation.

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Despite these serious complaints, few companies have taken the trouble to consider basic alternatives to their present marketing information arrangements. They are surprisingly slow to take advantage of new information-management concepts and technology. The typical attitudes seem to be that important marketing information eventually flows to the right executives, that each executive can gather best the information he needs, and that a system of information management carries the danger of manipulation.

My work with companies convinces me that these premises are wrong. Key executives are often abysmally ignorant of important marketing developments; they do not always make optimal use of existing information, and they frequently distort information in passing it on. A systematic solution to these problems is absolutely necessary if executives are to make effective and swift marketing decisions in an age characterized by intensifying competition, frequent product change, and complex and shifting customer wants.

The literature on total management information systems is singularly unin-

formative on the specific subject of marketing, and, while a small handful of progressive companies are conducting their own experiments, these are either undisclosed or revealed in a form too fragmentary to provide concrete guidance. This article will present a coherent view of the major concepts and design steps in developing a modern marketing information system.

Present Inadequacies

The marketing information requirements of the modern executive have changed radically in the postwar period, while the basic information arrangements have remained essentially the same.

On the one hand, the firm is involved in many more markets and products than ever before; the competitors are able to move more swiftly and deftly; and the environment of surrounding law, technology, economics, and culture is undergoing faster change.

On the other hand, executives must still hunt for their information from highly dispersed sources within and outside the company.The marketing research department typically supplies only a fraction of what is needed. The executive must also seek and receive information from the controller, the research and development department, the long-range corporate planning department, the legal department, the economic research department, and other parts of the company. He must supplement these findings by scanning hundreds of salesmen and dealer reports, and by reading half a dozen magazines and newspapers for possible items of significance. In short, he is on a perpetual information safari.

The marketing research department's primary obligations are to conduct special field studies, generate some routine reports and analyses of current sales, and send occasional clippings that might interest particular executives. On the other hand, it does not actively search for all sorts of marketing intelligence that might be needed by executives; it does not typically develop computer programs to aid in marketing analysis and decision making; and it generally does not render information evaluation, indexing, storage, and retrieval services, which would be the mark of a real information center. The marketing research department generally lacks—both in spirit and form—a conception of itself as the total information arm of the modern marketing executive.

One aspect of the insufficiency of information arrangements is dramatized in a planned experiment by Albaum. Albaum set out to study how well information flowed from the customers of a large decentralized company through company salesmen to company executives. He arranged with a sample of company customers to pass on six fabricated pieces of market information to company salesmen. The intelligence told of the changing requirements of customers, the building of a new factory by a competitor, the price being quoted by a competitor, the availability of a new material that might be used in making the product, and the development of a competitive product made from a new material. Clearly, all of these constitute useful marketing information in the right hands. Albaum wanted to discover how far, how fast, and how accurately this information would travel within the company.

Of the six pieces of market information, only two ever traveled beyond the company salesmen! For one reason or another, the majority of the salesmen chose not to pass on their intelligence to anyone in their company. Of the two reports that reached company executives, one arrived in three days but

was seriously distorted; the other arrived in about ten days in fairly accurate form, although its usefulness could have been impaired by its tardiness.[1]

Three Information Problems

Albaum's report suggests that at least three different problems arise in an unmanaged information system. They are (1) information disappearance: The salesmen may forget to relay information, may not know who can use it, or may purposely suppress it for personal reasons; (2) information delay: Intelligence takes longer than necessary to travel from the original relay point to the decision center; and (3) information distortion: The message becomes distorted in the process of being encoded, transmitted, and decoded many times. The likelihood of disappearance, delay, and distortion tends to increase with the number of relay points between the source and the final decision center.

Attempts at Correction

There are signs here and there that a few companies have recognized that these problems are sufficiently serious to warrant the development of new concepts and innovations. One such company is Du Pont:

> ...Du Pont is moving toward marketing information centers. Basically, it means storing in a computer a great deal of information about specific markets, your position and your competitor's in those markets, the vehicles which cover the markets, etc. When the time comes to make a move, all this information is at your fingertips, so you're working on facts, not hunches.[2]

Monsanto is another company that is taking steps to put marketing information on a technologically advanced footing. Wherever feasible, the computer has been harnessed to supply rapid information and complex marketing analysis. Computer programs have been developed to help the executive select the best warehouse from which to ship an order, the best means of shipment, and the best allocation of customer sales effort. Computer programs also are available to generate sales forecasts, customer profitability studies, analyses of sales call effectiveness, and pricing proposals.[3]

In addition, United Air Lines recently commissioned the Univac Division of Sperry Rand Corporation to build a $56 million on-line computerized system designed to provide United with a totally integrated reservations, operations, and management information capability. Applications will range from passenger reservations, complete name record storage, crew and aircraft scheduling, and flight and meal-planning data to air freight and cargo loading information.

Retailing is also showing signs of innovation in the area of marketing information. The Chicago department store of Carson Pirie Scott & Company recently installed an in-store system that enables its retail personnel to check a customer's credit in a matter of seconds by dialing the customer's number on a phone. The computer returns a spoken answer, either authorizing the sale or giving other instructions. Giant retailers are also experimenting with computerized inventory-ordering systems, direct computer lines to suppliers, and improved sales analysis systems.

[1] Gerald S. Albaum, "Horizontal Information Flow: An Exploratory Study," *Journal of the Academy of Management,* VII (March, 1964), 21–33.

[2] Malcolm McNiven, "An Interview with Malcolm McNiven," *Sales Management,* (April 19, 1963), 42.

[3] William A. Clark, "Monsanto Chemical Company: A Total Systems Approach to Marketing," in *Total Systems,* eds., Alan D. Meacham and Van B. Thompson (Detroit: American Data Processing Inc., 1962), pp. 130–42.

Other companies, such as the Hotpoint Division of General Electric, the Mead Paper Company of Dayton, Ohio, and General Mills, are known to be developing a total systems approach to their marketing information needs. But these companies still number only a handful. Other companies are interested but lack a comprehensive understanding of the marketing information problem or how to proceed to solve it.

The Major Information Flows

Every company is involved in three distinct marketing information flows (see Figure 1a). The first, the marketing intelligence flow, is the flow of information from the environment to relay points within the firm. Information on dealers, competitors, customers, government actions bearing on marketing, prices, advertising effectiveness, and so forth would be considered marketing intelligence. The second, the internal marketing information flow, is the flow between relay points within the firm. This includes intelligence as it flows through the company and internally generated reports germane to marketing. The third, or marketing communications flow, is the flow of information from the firm outward to the environment. It consists of both straight information and product and company promotion. The importance of marketing communications cannot be overemphasized, but, as an outward information flow, it will not concern us here.

The Marketing Intelligence Flow

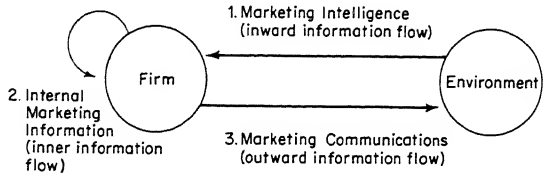
The flow of information known as marketing intelligence consists of salient facts about institutions and developments in the environment that affect the company's opportunities and performance. Figure 1b shows the nine major institutions in the environment that the firm monitors for marketing intelligence. It represents an elaboration of the marketing intelligence flow in Figure 1a.

"Marketing intelligence" is a broad term, embracing raw data, summary statistics, qualitative inferences, expert and lay opinions, impressions, and even rumors. Examples include figures showing that a certain important customer is beginning to divert some of his purchases to competitors, rumors that a competitor is developing a substantially improved product, and a survey indicating that many customers are dissatisfied with the service provided by the manufacturer's representative.

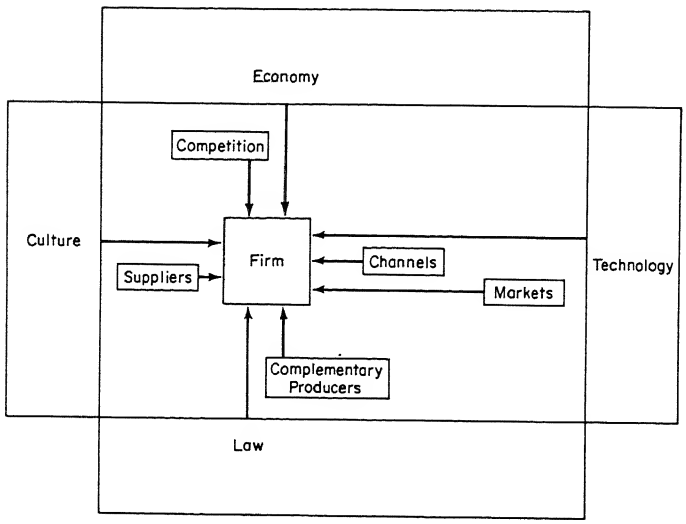
Each item constitutes marketing intelligence since it has potential action implications for one or more marketing executives in the firm. Information about a wavering customer is useful intelligence to a district sales manager, although it would be trivial to the new product manager. Reports about a competitor's development of a new product would be useful to the new product manager, and information about customer dissatisfaction with the manufacturer's representative would be useful to the trade relations manager.

The idea of marketing intelligence comes from the military. The high level military decision maker is usually far removed from the battlefield and, therefore, totally dependent upon second-hand information in directing the battle. He requires continuous data on the current position of his troops, the occurrence and outcomes of skirmishes, and the plans of the enemy. He needs hunches and rumors, as well as hard facts.

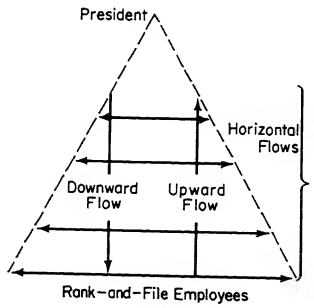
The marketing executive is in an analogous situation. He fights for terrain (markets) with allies (channels) against an enemy (competitors) for a



(a) THREE MARKETING INFORMATION FLOWS



(b) MAJOR SOURCES OF MARKETING INTELLIGENCE



(c) THREE TYPES OF INTERNAL INFORMATION FLOWS

Figure 1
What is meant by marketing information

prize (sales). Because he is remote from the battle scenes, he needs reports on the positions and effectiveness of his salesmen, on the resistances they are encountering, and on the activities of competitors. He needs current and accurate facts, as well as some of the talk and gossip of the marketplace.

Marketing intelligence varies in its availability. Information about broad characteristics of the market—such as the number of buyers or their geographical dispersion—is the easiest to obtain. The information is public and often can be drawn routinely from secondary sources—government and trade associations. Information about present and potential customer preferences and attitudes is a little more difficult to acquire. Generally, it does not exist in published form, and, since it may have to be gathered as primary information, its value must be considered carefully in relation to its cost. Most difficult to collect is information related to the marketing expenditures and plans of competitors. Such facts are tightly controlled for security reasons. The firm that wants it may have to develop an industrial espionage unit within the marketing intelligence unit. This, however, raises fundamental issues in business ethics.

The Internal Information Flow

A crucial point about marketing intelligence is that it must reach the right executive to be useful; the information must flow not only to the firm but through it. The internal flow is made up of downward, upward, and horizontal flows. The three are illustrated in Figure 1c where a pyramid form of organization is assumed. The downward flow consists of communications from higher company officials to subordinates. The upward flow consists of requisitioned, as well as unsolicited information, moving from lower to higher levels in the organization. The horizontal flow consists of information passing among company employees who occupy approximately the same levels.

In the typical company, these internal flows are left to take place in a natural unmediated way. It is assumed that employees generally will know where to find needed information within the company and will receive vital intelligence from others in the company as a matter of course. But these assumptions about the free flow of internal information in an unmanaged communications system are not justified, as Albaum's earlier cited study shows.

Examining Information Needs

At least three steps must be taken by the company that is serious about a total systems approach to marketing information. The first step is to appoint a responsible committee; the second is for this committee to develop studies of present information arrangements and needs. Third, the committee must design the new system on the basis of its studies and carry out its gradual implementation.

The Committee

Responsibility for the quality of marketing information should rest ultimately with the vice-president of marketing and his top ranking executives. This group must define the objectives that are to guide the supply of marketing information; it is also their responsibility to review the workings of the system and to institute desirable reforms.

These same men, however, are not equipped with either the time or training to play a firsthand role in studying,

designing, or implementing the improved system. The actual work must be done by a special team usually consisting of the following personnel: the marketing research director, the economic research director, a company sales force executive, a representative from the long-range corporate planning office, a representative from the controller's office, a company computer center specialist, and a company operations researcher (see Figure 2). Each man is on this committee, either because of his special concern for the quality of marketing information or because of his special skills in helping design efficient information systems.

Committee Studies

At its initial meetings, the committee will want to develop a consensus on broad objectives regarding the marketing information system and a general strategy for improvement. It will find, however, that substantial information is lacking on the present system, and that information must be collected. Two studies in particular will loom large in the future recommendations of this committee.



Figure 2
The marketing information systems committee

Internal Information Flow Characteristics. Elementary study of the flow of basic information through the company often leads to substantial improve-

ments. For example, what happens after the receipt of a customer purchase order? How long does the customer credit check take? What procedures are used to check inventory, and how long does this take? How soon does manufacturing hear of new stock requirements? How long does it take for sales executives to learn of daily or weekly total sales?

Ringer and Howell reported a study of one company's order routing, which resulted in cutting down the elapsed time between the receipt of an order and the issuance of the order to be filled from sixty-two hours to thirty hours without any change in costs.[4] Evans and Hague showed how advanced information flow charting techniques could be used to describe and improve interoffice and intraoffice information flows.[5]

The effect of information delays on marketing and manufacturing efficiency has been studied most intensively by Forrester at M.I.T. Using simulation techniques, Forrester is able to show how various delays in the processing and transmission of information lead to marketing decisions that often accentuate production fluctuations beyond those caused by forecasting errors and resource immobilities. His technique enables an estimate to be made of the cost-benefit effects of proposed alterations in the speed of information transmission through the organization.[6]

Executive Marketing Information Needs. The committee also will want direct feedback from executives on their satisfactions and dissatisfactions with current marketing information. Sampling of a small but representative group of executives from different levels and parts of the organization is adequate. The purpose is not to find out individual needs at this stage since information appetites and decision-making styles differ from executive to executive. Rather, the purpose is to determine how the information needs of product managers, territorial sales managers, customer account executives, advertising managers, salesmen, and other types of executives differ from each other.

Executive attitudes can be surveyed in a number of ways, including interoffice mail or the telephone. The best technique, however, is through personal interviews. Figure 3 suggests the major

Figure 3

Sample questionnaire for determining marketing information needs

1. What types of decisions are you regularly called upon to make?
2. What types of information do you need to make these decisions?
3. What types of information do you regularly get?
4. What types of special studies do you periodically request?
5. What types of information would you like to get which you are not now getting?
6. What information would you want daily? weekly? monthly? yearly?
7. What magazines and trade reports would you like to see routed to you on a regular basis?
8. What specific topics would you like to be kept informed of?
9. What types of data analysis programs would you like to see made available?
10. What do you think would be the four most helpful improvements that could be made in the present marketing information system?

[4] Jurgen F. Ringer and Charles D. Howell, "The Industrial Engineer and Marketing," in *Industrial Engineering Handbook,* 2d ed., ed. Harold Bright Maynard (New York: McGraw-Hill Book Company, 1963), pp. 10, 102–3.

[5] Marshall K. Evans and Lou R. Hague, "Master Plan for Information Systems," *Harvard Business Review,* (January–February, 1962), 92–104.

[6] Jay W. Forrester, "Advertising—A Problem in Industrial Dynamics," *Harvard Business Review,* (March–April, 1959), 100–110.

types of executive responses sought. The questionnaire covers the executive's information sources, attitudes, needs, and suggestions. The questions are stated mainly in an open-end fashion to encourage more involvement and frankness on the part of executives. Results will be more difficult to tabulate, but open-end surveys lead to deeper insights into the problem being studied.

Developing a Long-Range Plan

The studies of the present information flows and executives' needs provide the basis for developing a long-range plan for improving the marketing information system. The committee will not accept all suggestions because the value of additional or faster information must always be measured against the costs of providing it. The committee's task is to rate the various information needs against their probable contributions to better decision making and control. The resulting long-range plan would be submitted to the executive committee for comment and approval, and would be implemented in a series of steps over a number of years.

The Marketing Information and Analysis Center

This section will describe a blueprint for an organizational unit that promises to improve the accuracy, timeliness, and comprehensiveness of executive marketing information services. This unit is a generalization of the marketing research department into something infinitely more effective known as the Marketing Information and Analysis Center (MIAC). MIAC will function as the marketing nerve center for the company and will not only provide instantaneous information to meet a variety of executive needs but also will develop all kinds of analytical and decision aids for executives—ranging from computer forecasting programs to complex simulations of the company's markets.

The concept of this center can be understood best if we view its functions as being completely user oriented. It is designed to meet the total planning, implementational, and control needs of the modern marketing executive. Figure 4 shows the flow of marketing information from ultimate sources to and through MIAC to those who use this information. The ultimate sources consist of parties outside the firm, such as customers, dealers, suppliers, and competitors (see Figure 1b), and parties inside the firm, such as the accounting department, the economic and forecasting department, and the field sales force. The ultimate users consist of company executives, such as product managers, sales force managers, advertising managers, traffic managers, and production scheduling personnel. The MIAC stands between these two groups and performs over a dozen different services to enhance and expedite the marketing information and decision-making process. These information services break down into three major types: gathering, processing, and utilization.

Information Gathering

Gathering involves the effort to develop or locate information sought by company executives or deemed to be relevant to their needs. This function is made up of three constituent services.

The first is search, which is activated by requests for specific marketing information. Search projects can range from quick "information please" inquiries to large-scale field marketing studies. Marketing research departments traditionally spend a substantial portion of their time in search activity.

The second information gathering service is scanning. This describes MIAC's responsibility for assembling gen-

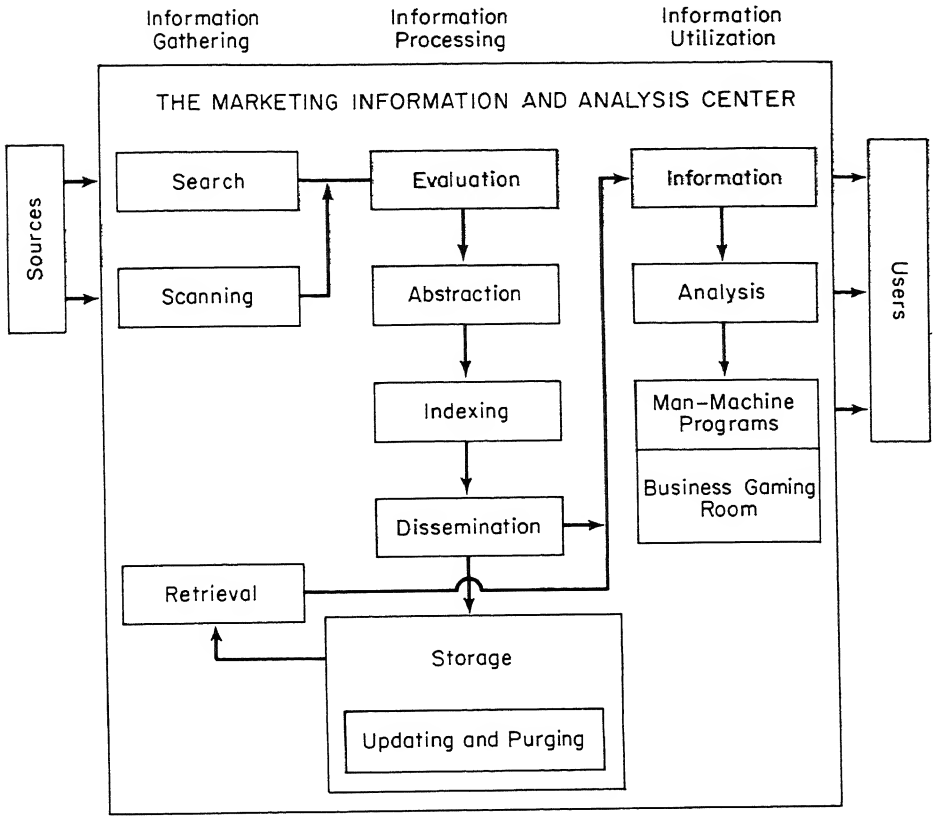


Figure 4
A schematic diagram of MIAC's information services

eral marketing intelligence. Intelligence specialists in MIAC will regularly scan newspapers, magazines, trade journals, special reports, and specific individuals to uncover any developments that might have import for one or more company executives. This partially relieves executives from the necessity to scan endless reams of written material for the sake of finding only a few items of interest. Because executives have overlapping information interests, the centralization of this function and its delegation to MIAC is likely to save considerable executive time. Its effectiveness, however, depends on how well MIAC personnel really understand the differing and specific information needs.

The third information gathering service is retrieval. When the needed information is already on file, the problem is to locate the information efficiently and speedily. This depends on the extent to which MIAC adopts advanced information storage and retrieval techniques, such as computer systems, microfilm devices, display consoles, and the like.

Information Processing

MIAC will also offer a variety of processing services designed to enhance the overall quality of the information. Five major services can be distinguished.

The first service is evaluation. One or

more MIAC staffers trained in techniques of data validation would offer a technical opinion as to how much confidence might be placed in a piece of information. The amount of confidence depends upon how the information was gathered, the size of the sample, the reliability of the source, and other considerations that the data evaluator would immediately recognize as pertinent. This service would offset the tendency to treat all information as equally valid. The data evaluator may show that a particular consumer panel market share figure may vary 20 per cent from the true value (at the 95 per cent confidence level) and that a magazine readership estimate may vary by as much as 50 per cent from the true figure. These opinions on the reliability and credibility of information will temper executive judgments in making decisions.

A second important service is information abstraction. Marketing information comes to MIAC in highly discursive forms. Many executives do not want to read pages and pages of reports to get a kernel of information. Trained abstracters on MIAC's staff condense and edit incoming information; they may omit important material, but this risk must be balanced against the gains accruing from a service that sharpens up information and supplies the executive with an immediate sense of what is relevant.

A third important service is that of indexing the information. This involves devising a set of descriptors that will permit its efficient classification for storage and retrieval purposes and a ready identification of which executives might be interested in it. For example, information about a proposed merger of two supermarket chains in California might be assigned the descriptors "supermarkets," "mergers," and "California," so that marketing executives interested in either supermarkets, mergers, or California would find this information readily. Developing a good indexing system is the key to the rapid dissemination of marketing information among the right parties and to its easy retrieval.

Dissemination is a fourth important information processing service. Dissemination involves getting information to the right people in the right form in the shortest feasible time. Among the devices used are periodic newsletters, telephone calls, teletype services, and interconnected company computers. Companies are experimenting with new and bolder dissemination procedures, as the following two examples show.

A large chemical company compiles during the week news of special interest to its salesmen, records the news on magnetic tapes, and sends the tapes to them. Each salesman's car is equipped with a tape recorder, and the salesmen pass many otherwise idle driving hours assimilating relevant marketing and company information.

A large supermarket chain is considering the idea of preparing up-to-the-minute reports of news affecting store operations, which its managers around the country can dial into.

MIAC's final information processing service is that of storage. Every company must find an efficient way to store and compress the mountains of information that come in yearly; otherwise, it is storage without utility. Executives should be able to put their fingers on past sales figures, costs, dealer data, and other information with minimum effort. The engineering of an efficient system is a problem for the technicians. Each company must determine the economically desirable life of different types of information so that it can be periodically updated and purged.

Information Utilization

MIAC must offer more than information gathering and processing services if it is to add substantial leverage to the executive's planning and control capabilities. The executive basically needs three types of staff assistance.

His first need is for information itself. Under this heading fall periodic reports, special market studies, and general marketing intelligence. We have seen how MIAC represents an improved vehicle for these services over the traditional marketing research department.

The second major need is for assistance in analysis. In this connection, MIAC's staff would include research specialists in statistical analysis, econometric analysis, psychometric analysis, and operations research, as well as research generalists to gauge needs and interpret results. These analysts would assist the decision maker in formulating problems and developing models for a solution. They would be able to specify the data needed and analyze the gathered data for important relationships and parameters. In this way, complex marketing decisions, such as dropping a price, revising sales territories, or increasing the advertising expenditure level, can be pre-evaluated and post-evaluated through the scientific analysis of available data. These analysts would also help make periodic analyses of distribution costs, sales trends, expense records, and product and salesman performances.

The third major need of the executive is for computer programs which will enhance his power to make decisions and to control operations. Future management gains in decision-making effectiveness will depend on the development of "man-computer" systems of decision making. Cohen and Miller have defined this type of system in the following way:

> ...it makes use of mathematical models (processed by a computer) to arrive at many decisions, but requires management to monitor these decisions and make others that are less subject to programming. The computer not only relieves the firm of much clerical work in handling and compiling the data, but it permits the use of mathematical techniques for optimizing certain decisions which involve large quantities of data and numerous calculations. Where models are not available, the computer often can produce information, from data on hand, to permit more efficient decisions.[7]

The nature of this new and growing service area is best conveyed by several examples.

A large paper company is developing a computer hookup among its plants and warehouses, which will permit salesmen to obtain quick answers to customers' questions concerning how soon they might receive the goods if they placed an order. The inquiry is entered at a console and transmitted to the central computer system where a determination is made as to whether the item is in stock. If it is in stock, the computer indicates how long it would take to schedule its production and ship it to the customer. The salesman can give the customer his answer in a number of minutes.

At a large chemical company, an executive can have a statistical demand analysis made for any product or product item by entering its past sales into the console. The computer program selects the economic and other variables (from a set of 200), which are most highly correlated with the product's past sales and prints out the resulting demand equation.

At a large packaged food company, sales executives get weekly reports on deliveries

[7] Kalman J. Cohen and Merton H. Miller, "Management Games, Information Processing, and Control," *Management International,* III (1963), 168.

to retail trade with a red asterisk after those figures showing unusual variances from norms. The red asterisks alert the executives to look into these situations and determine if any special measures are needed.

A large department store is experimenting with a computer program that can make ordering, pricing, and markdown decisions on some staple items and thus free buyers' time for the less routine decisions.

A major advertising agency uses the computer to develop an initial media plan, which will optimize on the clients' objectives, given the available information and constraints. The computer's proposed plan is then refined by changing certain assumptions or information, or by modifying it according to more intangible considerations.

A large chemical company uses a computer program to help evaluate each new product's promise at any point in its development. The executive enters the best information at his disposal regarding probable price, advertising, size of market, competitive strength, cost of development, and so forth, and the computer prints out possible rates of return and their respective probabilities.

A major electrical manufacturer uses a large and complex computer model of the company's markets for one of its products to pretest the likely effects of alternative trade promotions on competitors, customers, and final sales.

All of these are contemporary examples of the possibilities that lie in the exploitation of the man-machine interface. The ultimate implication is the development of a business gaming room, as part of MIAC, where information comes in continuously on field operations and is evaluated, indexed, abstracted, and disseminated; important developments lead to speedily arranged executive meetings to decide on marketing defensive or offensive actions. Information can be retrieved instantly as the meeting progresses, and the executives can pretest proposed moves on a simulation model of the relevant markets.

There is considerable evidence that executives are dissatisfied with the quality and quantity of their marketing information. Contemporary information systems are usually inadequate to supply the information and analysis needed by marketing and other company executives to respond rapidly and optimally to changing opportunities and challenges. Only a handful of companies are presently pioneering an assortment of innovations, which promise to synthesize one day into the outlines of a new and more effective marketing information system.

A look at the nature and types of information flows provides perspective on planning an improved system. The plan of attack for an organization serious about improving its system calls for the formation of a systems committee, studies of present information flows and executive information needs, and a long-range plan for progressive improvement of the information services. The nerve center of such a system, MIAC, carries out information gathering, processing, and utilization services, which go far beyond those observed in traditional marketing research departments.

The description of MIAC is more a blue-print for the future than a feasible system for the present. Marketing information systems cannot be overhauled overnight. Yet present systems can be guided to evolve in the direction of this blueprint. Difficult questions have to be answered concerning the proper relation between MIAC and other company information centers, the proper relation between MIAC and grass roots marketing research efforts by company per-

sonnel, the proper administrative arrangements within MIAC, the cost of MIAC, and so forth.

It must also be asked what the dangers may be in the centralized management of marketing information, and whether this system could make a fetish of information, causing more to be gathered than is economically justifiable. There are no general answers to these questions. They call for inventiveness and good judgment on the part of individual firms. The only judgment to be ventured here is that companies now have it within their power to make substantial improvements in their marketing information system—and can ill afford to neglect them.

Editorial Comment for Chapter 6

Although the readings in this chapter are primarily addressed to information relevant to production and marketing decisions, the reader should not lose sight of the fact that ideally this information should be incorporated in integrated planning and control models of the types presented in Chapter 5. Models such as cost-volume-profit and PERT/Cost have applications beyond the functional areas of production and marketing. Network models, for example, have been suggested to facilitate the preparation of an annual profit plan or budget.[1] And C-V-P analyses, naturally, have potential relevance to any decision involving financial consequences.

The literature of C-V-P analysis (or its less descriptive title—"break-even analysis") can trace its origins at least as far back as the nineteenth century, according to Carl Devine.[2] During the past two decades the number of articles on the subject has burgeoned beyond reasonable count. These articles may be categorized along the following lines:

1. Those that are essentially repetitions of prior articles
2. Those that advocate refinements to deterministic forms of C-V-P
3. Those which favor integration with other models, such as linear programming
4. Those that urge extension of C-V-P from a one-period analysis to a multiperiod analysis
5. Those advocating introduction of probability concepts to C-V-P analysis

In terms of the number of articles, the first category must be granted the dubious distinction of being undisputed champion. The articles in this category are generally characterized by well-known illustrations showing applications of C-V-P analysis and, somewhat less often, a discussion of its limitations because of such simplifying assumptions as linearity and constant inventory levels.

The second category of articles is addressed to means of relaxing some of the simplifying assumptions of traditional C-V-P analysis. For example, Patrick[3] and, more recently, Solomons[4] adapt the analysis to situations in which absorption

[1] See Gordon B. Davis, "Network Techniques and Accounting—with an Illustration," *N.A.A. Bulletin,* XLIV (May, 1963), 11–18.

[2] Carl Thomas Devine, "Accounting," *Encyclopaedia Britannica* (1964 edition), VI, 590.

[3] A. W. Patrick, "Some Observations on the Break-Even Chart," *The Accounting Review,* XXXIII (October, 1958), 573–80.

[4] David Solomons, "Breakeven Analysis Under Absorption Costing," *The Accounting Review,* XLIII (July, 1968), 447–52.

costing rather than direct costing is being used. Soldofsky[5] and Vickers[6] advocate that C-V-P analysis be brought into closer conformity with economic theory and, hence, suggest that the simplifying assumptions concerning cost and revenue behavior be critically re-examined.

The relationship of C-V-P and linear programming techniques has been discussed by Jaedicke,[7] and Charnes, Cooper, and Ijiri.[8] The Jaedicke article illustrates, by means of a linear programming analysis, that in product-combination decisions, the choice of products on either the basis of lowest break-even point or highest contribution to profit per dollar of sales is likely to be nonoptimal. Charnes, Cooper, and Ijiri show how a simple break-even model may be extended to produce a coordinated budgetary planning model.

Manes[9] extends C-V-P from its usual one-period analysis to a multiperiod analysis. In the one-period case it is generally assumed that no additional investment in new facilities is required. In other cases the fixed costs of plant are not yet committed, and management is interested in estimating the level of output required to break even and attain budgeted profit. To generate this type of information, Manes introduces the cost of capital consideration and shows the relationship between break-even analysis and the capital budgeting problem.

The fifth category of articles is concerned with an explicit recognition of risk and uncertainty. The Jaedicke and Robichek reading falls into this category. There is a central theme that transcends this reading and other articles dealing with probabilistic models that require subjectively generated inputs. This theme suggests that an analysis with an explicit expression of the shape of the decision maker's uncertainty is far superior to an analysis that suppresses uncertainty in the form of deterministic "most likely" estimates. It can be argued that "most likely" estimates are the result of an informal aggregation of a number of mental calculations by the decision maker and that a plea for probabilistic inputs is essentially a plea for uncoupling the aggregated output by displaying the inputs in a more formal manner. Despite the apparent merits of probabilistic C-V-P models, normal guidelines of information economics should be applied to each decision situation. For example, in those rare instances where the range of uncertainty is limited and estimated to be approximately normally distributed, the incremental benefits of a probabilistic model are likely to be modest. Finally, as Jaedicke and Robichek point out, the probabilistic model cannot effectively serve decision making until the firm's attitude toward risk is properly assessed.

Network analysis can be potentially employed when the following five criteria are met:

[5] Robert M. Soldofsky, "Accountants' vs. Economists' Concepts of Break-even Analysis," *N.A.A. Bulletin,* XLI (December, 1959), 5–18.

[6] Douglas Vickers, "On the Economics of Break-Even," *The Accounting Review,* XXXV (July, 1960), 405–12.

[7] R. K. Jaedicke, "Improving B-E Analysis by Linear Programming Techniques," *N.A.A. Bulletin,* XLII (March, 1961).

[8] A. Charnes, W. W. Cooper, and Y. Ijiri, "Breakeven Budgeting and Programming to Goals," *Journal of Accounting Research,* I (Spring, 1963), 16–43.

[9] Rene Manes, "A New Dimension to Breakeven Analysis," *Journal of Accounting Research,* IV (Spring, 1966), 87–100.

1. There is a definite *objective* that can be achieved at a given point in time (objective event).
2. There is a *completion-date* requirement for the objective event.
3. There are many *identifiable and interdependent* activities and events that must be completed in proper sequence before the objective event can be achieved.
4. *Time estimates* can be made for the events and activities in the network.
5. *Resources* can be *shifted* from one activity to another in order to affect the completion date of activities in the network.[10]

The diversity of projects which actually lend themselves to network techniques is impressive. A representative listing would include, among others: construction of a building or other facility, maintenance project planning, new product introduction, bidding preparations, installation and debugging of a computer system, and research and development project scheduling.

PERT/Cost represents a relatively recent stage in the development of management systems for planning and controlling project time, cost, and technical performance. The widespread acceptance of PERT/Time in both commercial and government applications has provided considerable impetus for PERT/Cost. At the conclusion of the De Coster paper, eight implementation problems associated with PERT/Cost are enumerated. Interestingly, seven are related either to data gathering or to integrating PERT/Cost systems into existing accounting systems.[11] For PERT/Cost purposes a firm's cost accounting system must be designed to facilitate cost accumulation by work packages—the lowest level of planning and control in PERT/Cost systems. Based upon the experiences of four companies, one writer reports that not only can PERT/Cost be accommodated within the framework of existing accounting systems, but where a modern accounting system exists very little modification is necessary.[12]

Although social, political, and economic environmental data, as well as competitive data, are becoming increasingly more critical as a basis for strategic planning, many firms continue to place almost exclusive emphasis on internal data. Nowhere is the need for environmental and competitive data more apparent than in the area of marketing information systems. Aguilar's study, conducted among managers of chemical manufacturing companies and a number of other industries, found that no category of external information interested managers as much as "market tidings." This classification includes the following items enumerated earlier in the Editorial Comment for Chapter 1:

1. Market potential. Supply and demand considerations for market areas of current or potential interest: e.g., capacity, consumption, imports, exports
2. Structural change. Mergers, acquisitions, and joint ventures involving competitors; new entries into the industry

[10] Davis, *op. cit.*, p. 14.

[11] For further discussions of these problems see Laurence S. Hill, "Some Cost Accounting Problems in PERT/Cost," *Journal Of Industrial Engineering,* XVII (February, 1966), 87–91; Peter P. Schoderbek, "PERT/Cost: Its Values and Limitations," *Management Services,* III (January–February, 1966), 29–34; Wilbur R. Ross, "Accounting Aspects of PERT/Cost," *Management Accounting,* XLVIII (April, 1967), 47–51.

[12] Ross, *ibid.*, p. 50.

3. Competitors and industry. General information about a competitor, industry policy, concerted actions in the industry, and so forth
4. Pricing. Effective and proposed prices for products of current and potential interest
5. Sales negotiations. Information relating to a specific current or potential sale or contract for the firm
6. Customers. General information about current or near-potential customers, their markets, their problems[13]

Information disappearance, delay, and distortion are cited as undesirable outgrowths of unmanaged information systems. To improve the accuracy, timeliness, and comprehensiveness of marketing information systems, Kotler proposes the development of an organizational unit known as the Marketing Information and Analysis Center (MIAC). The functions of MIAC, as displayed in Figure 4 in the Kotler reading, could well serve as a blueprint for the total management information system, and not the marketing segment alone. Let us briefly examine some of these MIAC functions.

Information gathering involves three principal activities: search, retrieval, and scanning. Search and retrieval are activities based upon specific management requests, and the resulting product is properly classified as "solicited information." With a capable MIAC staff, the delegation of these two information-gathering activities involves relatively little risk. The third information gathering service, scanning for general marketing intelligence, is a much less structured activity, and its product is not subject to advance detailed specification. In this sense, it may be viewed as "unsolicited information." There appear to be substantial risks of information disappearance, delay, or distortion when scanning becomes essentially a staff activity. Delegation of scanning to a MIAC staff presupposes that the staff would be able to recognize the relevance of information. This recognition requires the scanner to comprehend available information and be aware of issues actually or potentially important to decision makers.[14] Clearly, the degree to which scanning activity shall be delegated from executives to staff must be carefully weighed. Aside from the problem of delegating, there is a positive rationale for preserving some aspects of this activity for executives. Environmental scanning often serves as an idea generator and catalyst to executive creativity. While the payoffs in this respect are difficult to measure, they can be strategic to the continuing growth and vitality of an organization.

Kotler includes evaluation, abstraction, indexing, and dissemination as elements of information processing. In an effective information system, each of these activities must be well executed. Abstraction, especially, should be handled by information specialists having great empathy for top management's role and a strong sense of the relevance of information. Similar skills would be required for Kotler's suggested interpretation phase for more effective information utilization.

[13] Francis Joseph Aguilar, *Scanning the Business Environment* (New York: The Macmillan Company, 1967), p. 40.
[14] *Ibid.*, p. 14.

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7

Information for Evaluation of Risky Capital Investments

UNCERTAINTY AND ITS EFFECT ON CAPITAL INVESTMENT ANALYSIS

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When uncertainty concerning costs, revenues, and project life exists, classical measures of capital investment return are limited in value. Sensitivity analysis indicates that relatively small overestimates and underestimates create relatively large errors in the discounted rate of return for different types of return schedules. Perhaps, then, businessmen are justified in seeking other methods of project evaluation.

This article is concerned with one specialized aspect of capital budgeting: the usefulness of "theoretically correct" choice criteria[1] in real-world investment decisions.

There are other areas of capital

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[1] Without entering into unnecessary debate, present value and the discounted rate of return are simply defined for the purposes of this article as "theoretically correct" criteria.

budgeting that are surely much more important, but this one deserves special attention because so many recommendations, explicit and implicit, based on these criteria have bombarded the businessman.[2] Before we assail the business practitioner for his crude and unscientific methods, we should be sure that our theory will provide better total results than his unsophisticated decision rules.

There is general agreement that if investment parameters, such as costs, revenues, salvage values, and interest rates, were amenable to accurate prediction, theoretically correct methods could be used to great advantage in most firms. But all capital investments involve uncertainty in one form or another. The contention of this article is that theoretically correct choice criteria have *limited practical value due to the uncertainty involved in the estimates required for the analysis.*

A General Analysis of Estimating Errors

Two types of investments are considered: investments with constant annual returns and investments with declining annual returns. The discussion centers on two hypothetical illustrations that have been purposely framed for easy calibration of errors. We ignore errors in salvage values.

Proposals with Constant Annual Returns

Suppose we estimate that an investment will yield \$1,000 annual pre-tax returns[3] for 7 years. Assuming the supply price of the asset is \$4,000, a 32 per cent tax rate, straight line depreciation over the life of the asset, and no terminal salvage value, the post-tax discounted rate of return would be 11.6 per cent. Now if the proposal lasts only 6 years, all else remaining equal, the discounted rate of return is 9.1 per cent. This means that the actual return is 2.5 percentage points less. On the other hand, if the proposal lasts for the predicted 7 years but returns \$800 per year (before taxes) instead of \$1,000, the discounted rate of return falls to 6.5 per cent which is 5.1 percentage points less than the estimate.[4] There is a plethora of possible combinations of returns, lives, and rates of return. The simplest way to illustrate these relationships is to graph them as in Figure 1. Shown are lines connecting the discounted rates of return for proposals with the same life and different pre-tax annual returns. The line labeled *7 years* shows the discounted rates of return for all investments with a life of 7 years. As the pre-tax returns decrease, the discounted rate of return declines. For this reason the lines slope downward to the left.

In evaluating the effect of uncertainty, we can use Figure 1 to determine the possible variations in the discounted rate of return when uncertainty exists. (The data used to construct Figure 1 are shown in Table 1.)

How much variation then in the discounted rate of return could we expect with this amount of error? If the returns of this estimated 7 year-\$1,000 per year investment are subject to an error of plus or minus 2.5 per cent and plus or minus one year, the maximum

[2] For example, see Harold Bierman and Seymour Smidt, *The Capital Budgeting Decision* (New York: The Macmillan Company, 1960).

[3] *Returns* is used here to mean the excess of revenue over out-of-pocket cost.

[4] The discounted rate of return is used instead of present value. The reason for using this criterion is that the discounted rate of return is conceptually more simple. The same conclusions hold here whether present value or discounted rate of return is used.

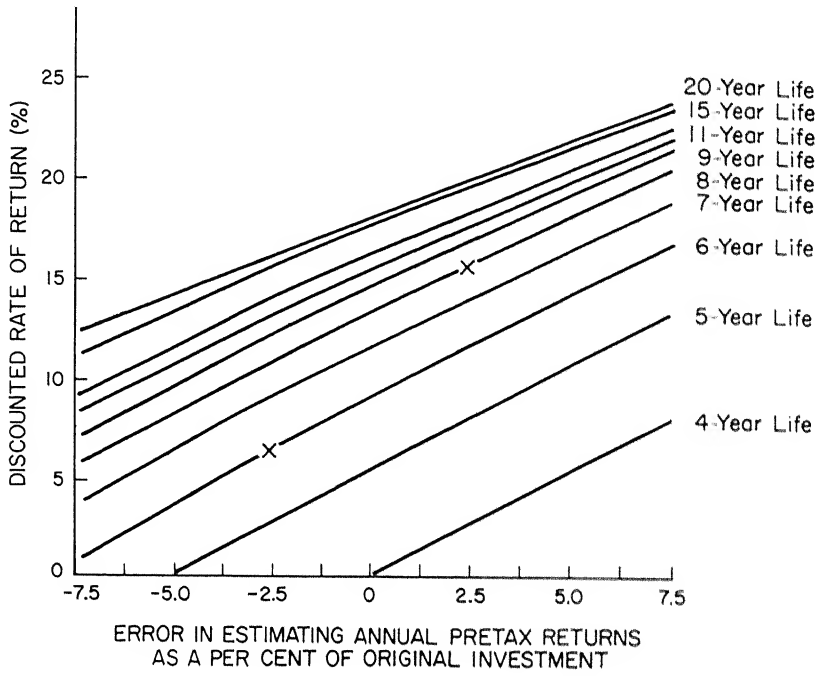


Figure 1

Constant annual pre-tax returns

and minimum rates of return are 15.6 per cent and 6.5 per cent (as shown in Figure 1 by the X's).[5] This is a variation of about 9 percentage points. If we extended the possible error to plus or minus two years, the maximum and minimum rates are 16.8 per cent and 2.8 per cent, a variation of 14 percentage points. Errors in estimates of these magnitudes do not appear at all unlikely.[6] This much uncertainty would seem to discourage the use of theoretically correct rationing methods for ranking investment proposals. There may be no significant difference among proposals' rates of return if they are nearly equally profitable, and if one or more proposals are obviously more profitable than the others, "alternative" methods[7] provide the same information with less cost.

Another interesting feature of Figure 1 is that it provides some insight into the effect of errors in length of life versus error in returns. The relationship between annual pre-tax return and the discounted rate of return is close to linear with a slope of about .02 to .03. This means that an estimating error of about 1 per cent results in an error of about 2 to 3 percentage points in the discounted rate of return. This relationship is fairly constant through-

[5] In Figure 1, −7.5 per cent represents annual pre-tax returns of $700; −5.0 per cent represents returns of $800; −2.5 per cent represents returns of $900, etc. The percentage errors are percentages of the original investment, ($4,000). That is,

($700 − $1000)/$4000 = −7.5 per cent
($800 − $1000)/$4000 = −5.0 per cent
($900 − $1000)/$4000 = −2.5 per cent.

[6] See Martin B. Solomon, Jr., *Investment Decisions in Small Business* (Lexington, Ky.: University of Kentucky Press, 1963).

[7] Alternative methods, such as the payback period, rate of income on investment, or the MAPI urgency rating.

TABLE 1

The Effect of Estimating Errors on the Discounted Rate of Return—Constant Annual Pre-Tax Returns

Life of the Proposal	*Annual Pre-Tax Return*												
(Years)	*$700*	*$750*	*$800*	*$850*	*$900*	*$950*	*$1,000*	*$1,050*	*$1,100*	*$1,150*	*$1,200*	*$1,250*	*$1,300*
20	.122	.132	.142	.151	.161	.170	.180	.189	.198	.207	.216	.225	.234
15	.112	.123	.134	.144	.154	.165	.175	.184	.194	.204	.213	.223	.232
11	.092	.104	.116	.127	.139	.150	.161	.172	.182	.193	.203	.213	.223
10	.083	.096	.108	.120	.131	.143	.154	.165	.176	.187	.197	.208	.218
9	.072	.085	.097	.110	.122	.134	.145	.156	.168	.179	.190	.200	.211
8	.057	.071	.083	.096	.109	.121	.133	.145	.156	.168	.179	.190	.201
7	.037	.051	.065	.078	.091	.103	.116	.128	.140	.152	.163	.175	.186
6	.010	.024	.038	.052	.065	.078	.091	.104	.116	.129	.141	.153	.165
5	*	*	.010	.015	.028	.042	.055	.068	.081	.094	.107	.119	.131
4			*	*	*	*	.010	.014	.027	.041	.054	.066	.079
3							*	*	*	*	*	*	*

* Indicates negative discounted rate of return.

out. On the other hand, the relationship between discounted rate of return and length of life is not stable. As the life becomes shorter, an error of one year in the estimated life becomes more critical; the relationship is curvilinear. The difference in the rate of return between a life of 20 years and 15 years is only about one-half of one percentage point when pre-tax profits=$1,000 (zero or horizontal axis). The difference of only 2 years between a life of 4 and 6 years (with $1,000 returns) results in a change of more than 6 percentage points in the discounted rate of return. Perhaps this is a good reason for businessmen being particularly cautious about making length of life estimates.

The conclusions here are that standard formulations of theoretically correct rationing methods have limited usefulness when dealing with uncertainty.

Proposal with Declining Annual Returns

To make the analysis more complete, the case of declining annual returns is included.[8]

[8] An investment's estimated pre-tax returns are: $2,500 the first year. $2,400 the second year, $2,300, $2,200, $2,100, $2,000, $1,900. The estimated life of the investment is therefore 7 years. Errors in length of life are handled the same as before; that is, if the estimated life overstates actual life by one year, the actual investment would return $2,500, $2,400, $2,300, $2,200, $2,100, $2,000, or an actual life of 6 years instead of the estimated 7 years. This estimate, though in error as far as length of the life is concerned, is correct concerning the returns (0 on the horizontal axis). Errors in pre-tax returns indicate an error in the initial annual returns. For example, a −2.5 per cent error in estimating returns represents an investment that usually returns $2,300 the first year instead of the estimated $2,500. The annual decline in returns ($100 per year) remains constant. Thus, an investment whose life was correctly estimated as 7 years but whose returns were overstated by 2.5 per cent would return $2,300, $2,200, $2,100, $2,000, $1,900, $1,800, $1,700 (before taxes). In Figure 2, zero on the horizontal axis represents an investment with an actual initial return of $2,500 and a $100 annual decline in pre-tax returns. A + 3-year error in length of life (10-year life) and a −8.75 per cent error in estimated pre-tax

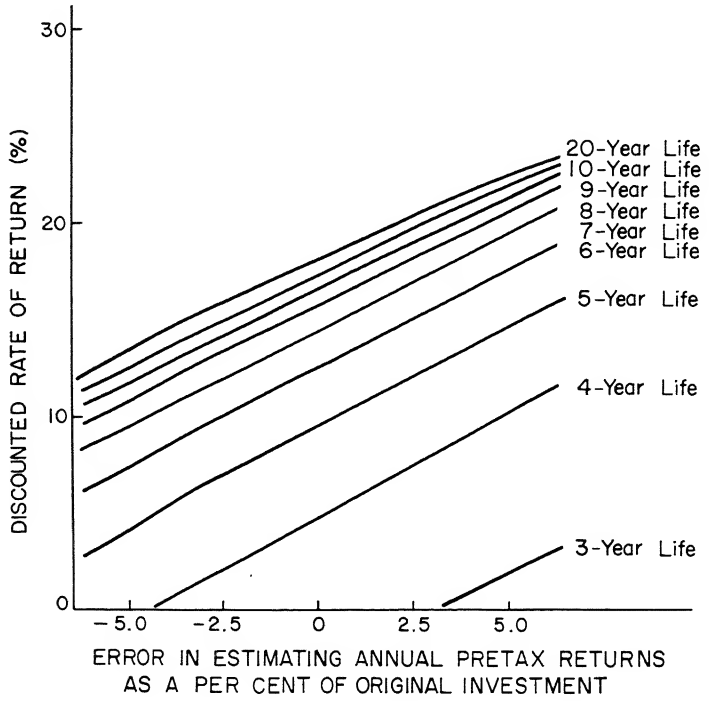


Figure 2

Declining annual pre-tax returns

The results are shown in Figure 2. There is much similarity between Figures 1 and 2 and most everything that has been said applies to both. The conclusions about uncertainty seem to apply equally to both constant and declining return investments.

Unless an investment will continue for a long period, a relatively small positive miscalculation in the estimate of length of life (2 to 3 years) can result in a serious overstatement of profitability.

returns would designate an investment that actually returns $1,800 the first year, $1,700 the second year, $1,600,..., $1,000. The cost of the investment is $8,000, the tax rate is 32 per cent, and straight line depreciation is used over the life of the asset with no terminal salvage value assumed. As before, errors are computed as a percentage of the original investment ($800 in this case).

The Effect of Technological Change

Because errors in returns are linear and errors in life are curvilinear, errors in estimating annual returns may average out over a large number of investments, whereas errors in length of life will not. Proposals that last less than the estimated life lower the average discounted rate of return for the firm more than proposals lasting longer than the estimated life raise the average.[9]

[9] This curvilinear phenomenon occurs whether we plot present values or discounted rates of return. It may, however, be more apparent than real. It stems from an assumption underlying the discounted rate of return: Proceeds are assumed to be reinvested at the rate of return for the original project; there is a cumulative effect of a high return project. If proceeds are not reinvested at this high rate but placed into low yield investments, this assumption does not hold and the curvilinear phenomenon is not operative.

Today, with technological advancement so rapid and innovation so frequent, it seems logical to assume that many capital investments will be subject to extremely high rates of obsolescence. Businessmen do not usually know which of their investments will become obsolete soon; they are understandably worried about proposals that require 10 years to pay for themselves. The farther into the future one predicts, the more uncertainty of obsolescence he is subjected to and the more unsure he is of the prediction.

By insisting upon proposals that pay back quickly, or by using a higher discount rate, within the realm of feasible prediction, the businessman is providing greater flexibility for himself and, in a rough way, taking into account the effects of uncertainty. He is in a better position to maneuver and change his plans when necessary but will accept fewer projects. His hope is that those projects that are rejected (that otherwise might be accepted) will become obsolete before earning a return.

Technological change is one difficulty in estimating length of life. Businessmen can search for information about the expected annual returns from a proposal, but it is generally much more difficult to do research on the length of a proposal's life. In addition, Figures 1 and 2 suggest that errors in length of life may be more serious. Use of the short payback period or higher discount rate tends to reduce errors of this type. The old saying about one in the hand being worth two in the bush in quite descriptive of business behavior in relation to projects in danger of obsolescence. It may be worthwhile to invest, receiving a small quick return than take a chance on a larger return or obsolescence.

Simple (or even simple-minded) methods of investment ranking may not be as absurd as some of the literature would lead us to believe, if used in a careful way by clever people; and although no one claims superiority for a payback method, it appears that in investment decisions confounded by large amounts of uncertainty, the present value and discounted rate of return rankings are so sensitive to estimating errors that the payback criterion may provide results that are about as good as any. The main point of this paper is to point out the sensitivity in discounted rate of return results and not to recommend alternative methods.

A REVIEW OF "UNCERTAINTY AND ITS EFFECT ON CAPITAL INVESTMENT ANALYSIS"[1]

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Solomon's contention that "standard formulations of theoretically correct rationing methods have limited usefulness when dealing with uncertainty" is challenged. A wider range of sensitivity tests or a risk analysis approach is suggested by Swalm.

A thought-provoking article by Martin B. Solomon, Jr. follows this abstract:

When uncertainty concerning costs, revenues, and project life exists, classical measures of capital investment return are limited in value. Sensitivity analysis indicates that relatively small overestimates and underestimates create relatively large errors in the discounted rate of return for different types of return schedules. Perhaps, then, businessmen are justified in seeking other methods of project evaluation.

Professor Solomon's conclusions are based on the examination of two variants of a single problem: In its simpler form the calculations are based on an investment of $4,000 which produces net pre-tax receipts of $1,000 per year for seven years, using a 32 per cent tax rate and straight line depreciation over the life of the asset. A sensitivity study is made by varying the return by up to ±2½ per cent of the original investment and the life by ±2 years.

The second version is the same except that the pre-tax returns are changed to $2,500 in the first year with a declining gradient of $100 per year.

Before discussing Solomon's conclusions, we might question the meaningfulness of his assumptions.

Presumably, the rationale behind a sensitivity study in which the life is varied includes the presumption that the life is difficult to predict for analytical purposes. If this is so, how could accountants manage successfully to predict the life for depreciation purposes, as Solomon's model assumes they do? And, on a more minor note, how generally applicable is a 32 per cent income tax bracket?

The conclusions from Solomon's investigations are nicely shown in two figures in which the discounted rate of return is plotted against the error in estimating pre-tax returns, expressed at a per cent of the original investment, for varying lives. He sums up the results, in the first example, by noting that errors of ±2 years life and ±2½ per cent of the original investment in the annual receipts yield maximum and minimum returns of "16.8 and 2.8 per cent, a variation of 14 percentage points." He goes on to say,

Errors of estimates of these magnitudes do not appear at all unlikely. This much uncertainty would seem to discourage the use of theoretically correct rationing methods for ranking investment proposals. There may be no significant difference among proposals' rates of return if they are nearly equally profitable, and if one or more proposals are obviously more profitable than the others, "alternative"

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[1] By Martin B. Solomon, Jr., in *Management Science,* XII (April, 1966), 334–39 (reprinted in this volume on pp. 278–83).

methods, such as the payback period, rate of income on investment, or the MAPI urgency rating, provide the same information with less cost.

After analyzing the second case a bit more briefly, Solomon says, "...most everything that has been said applies to both."

One cannot help but question Solomon's sweeping statement, based on such limited evidence, that, "[t]he conclusions here are that standard formulations of theoretically correct rationing methods have limited usefulness when dealing with uncertainty."

Surely such a conclusion requires more than two variants of a single example! Suppose, for example, that Solomon had chosen a second example in which an investment of $10,000 produced a net return of $5,000 per year for seven years. Applying his same criterion and assumptions (including, for the sake of comparison only, the dubious assumption that the life can be accurately predicted for depreciation purposes but not for analytic purposes) we can find the maximum and minimum rates of return corresponding to the limits Solomon chose by solving the following two equations for i (we use here Grant and Ireson's symbology):

$$10{,}000\,(CRF - i - 5) = 0.68\,(4750) + .32\,\frac{10{,}000}{5}$$

$$10{,}000\,(CRF - i - 9) = 0.68\,(5250) + .32\,\frac{10{,}000}{9}$$

Performing the simple arithmetic indicated and looking up the answer in a suitable set of interest tables, we find $i_{\min} = 28.0$ per cent and $i_{\max} = 36.9$ per cent. This would hardly justify Solomon's melancholy conclusion.

It is suggested that the example above is biased in about the same degree in a "favorable" direction as Solomon's is in an "unfavorable" direction from what might be termed a typical case. And, to be a bit unkind, the ease with which these results were obtained leads one to wonder at the special thanks offered in a footnote of the original article to "The University of Kentucky Computing Center and the U.S. Small Business Administration who generously supported this work."

Returning to Solomon's general statement that other methods, such as "rate of return on investment" (we presume him to mean the ratio obtained by dividing the income by the investment) provide "the same information at less cost," we note that if an investment of $3,000 produces an income of $1,000 per year, this ratio will be equal to .33 and will remain so regardless of the life of the project. But if the project lasts two years, it obviously pays a negative rate of return; if three years, a zero rate; if forever, a rate of return of 33 per cent. (This assumes the use of Solomon's "theoretically correct" end-of-year convention.)

In other words, given a choice between investment A which paid a "rate of return on investment" of .33 and B which paid .25, Solomon suggests that since the rate of return on investment criteria is as good as any, we might as well use it and choose A.

But suppose the A happened to have a life of 3 ± 1 year and the B a life of 12 ± 3 years. Surely, under any rational method, B should be chosen as superior!

This example is an approach to saying that, even accepting Solomon's melancholy remarks about the limitations of the "theoretically correct" method, it does not logically follow that other methods, whether selected at random or otherwise, are just as good.

Surely the contention that, given a stochastic process, one analytic method is superior to another requires at the very minimum a sensitivity study of

both methods, and probably a more refined tool than a simple sensitivity study will be required to choose between them.

In conclusion, sensitivity studies should be made more often, as Solomon suggests, but in order to draw general conclusions empirically, a wider range of test cases is needed (or at the very least, some evidence needs to be offered that indicates the particular test case chosen is typical) and studies need to be made of *all* proposed methods to permit a choice among them.

Perhaps Solomon's article will serve to remind us of the need for sensitivity studies in real-life studies, but if these studies indicate an unacceptably wide range of results, it is suggested that a probabilistic approach, along the lines suggested by Hertz[2] offers a more meaningful basis for a decision than returning to "crude or unscientific methods" as Solomon seems to suggest.

[2] David B. Hertz, "Risk Analysis in Capital Investment," *Harvard Business Review*, XLII (January–February, 1964).

STOCHASTIC DECISION TREES FOR THE ANALYSIS OF INVESTMENT DECISIONS

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This paper describes an improved method for investment decision making. The method, which is called the stochastic decision tree method, is particularly applicable to investments characterized by high uncertainty and requiring a sequence of related decisions to be made over a period of time. The stochastic decision tree method builds on concepts used in the risk analysis method and the decision tree method of analyzing investments. It permits the use of subjective probability estimates or empirical frequency distributions for some or all factors affecting the decision. This application makes it practicable to evaluate all or nearly all feasible combinations of decisions in the decision tree, taking account of both expected value of return and aversion to risk, thus arriving at an optimal or near optimal set of decisions. Sensitivity analysis of the model can highlight factors that are critical because of high leverage on the measure of performance, or high uncertainty, or both. The method can be applied relatively easily to a wide variety of investment situations and is ideally suited for computer simulation.

Investment decisions are probably the most important and most difficult decisions that confront top management, for several reasons. First, they involve enormous amounts of money. Investments of U.S. companies in plant and equipment alone are approaching $50 billion a year. Another $50 billion or

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so goes into acquisition, development of new products, and other investment expenditures.

Second, investment decisions usually have long-lasting effects. They often represent a "bricks and mortar" permanence. Unlike mistakes in inventory decisions, mistakes in investment decisions cannot be worked off in a short period of time. A major investment decision often commits management to a plan of action extending over several years, and the dollar penalty for reversing the decision can be high. Third, investments are implements of strategy. They are the tools by which top management controls the direction of a corporation.

Finally, and perhaps most important, investment decisions are characterized by a high degree of uncertainty. They are always based on predictions about the future—often the distant future. And they often require judgmental estimates about future events, such as the consumer acceptance of a new product. For all of these reasons, investment decisions absorb large portions of the time and attention of top management.

Investment decision-making has probably benefited more from the development of analytical decision-making methods than any other management area. In the past ten or fifteen years, increasingly sophisticated methods have become available for analyzing investment decisions. Perhaps the most widely known of these new developments are the analytical methods that take into account the time value of money. These include the net present value method, the discounted cash flow method, and variations on these techniques (4, 9). Complementary to these time-oriented methods, a number of sophisticated accounting techniques have been developed for considering the tax implications of various investment proposals and the effects of investments on cash and capital position (2, 13, 16). Considerable thought has been given to the proper methods for determining the value of money to a firm, or the cost of capital (9, 13). The concepts of replacement theory have been applied to investment decisions on machine tools, automobile fleets, and other collections of items that must be replaced from time to time (16).

In a somewhat different direction, techniques have been developed for the selection of securities for portfolios. These techniques endeavor to select the best set of investments from a number of alternatives, each having a known expected return and a known variability (12). In this context, the "best" selection of investments is that selection that either minimizes risk or variability for a desired level of return or maximizes return for a specified acceptable level of risk. (In general, of course, it is not possible to minimize risk and maximize return simultaneously.) The application of these techniques to corporate capital budgeting problems is conceivable but not imminent.

In the evolution of these techniques, each advance has served to overcome certain drawbacks or weaknesses inherent in previous techniques. However, until recently, two troublesome aspects of investment decision making were not adequately treated, in a practical sense, by existing techniques. One of these problems was handling the uncertainty that exists in virtually all investment decisions. The other was analyzing separate but related investment decisions that must be made at different points in time.

Two recent and promising innovations in the methodology for analyzing investment decisions now being widely discussed are directed at these two problems. The first of these techniques is commonly known as risk analysis (6, 8); the second involves a concept

known as decision trees (10, 11, 15). Each of these techniques has strong merits and advantages. Both are beginning to be used by several major corporations.

It is the purpose of this article to suggest and describe a new technique that combines the advantages of both the risk analysis approach and the decision tree approach. The new technique has all of the power of both antecedent techniques, but is actually simpler to use. The technique is called the stochastic decision tree approach.

To understand the stochastic decision tree approach, it is necessary to understand the two techniques from which it was developed. A review of these two techniques follows.

A Review of Risk Analysis

Risk analysis consists of estimating the probability distribution of each factor affecting an investment decision, and then simulating the possible combinations of the values for each factor to determine the range of possible outcomes and the probability associated with each possible outcome. If the evaluation of an investment decision is based only on a single estimate—the "best guess"—of the value of each factor affecting the outcome, the resulting evaluation will be at best incomplete and possibly wrong. This is true especially when the investment is large and neither clearly attractive nor clearly unattractive. Risk analysis is thus an important advance over the conventional techniques. The additional information it provides can be a great aid in investment decision making.

To illustrate the benefit of the risk analysis technique, Figure 1 shows the results of two analyses of an investment proposal. First, the proposal was analyzed by assigning a single "best guess" value to each factor. The second analysis used an estimate of the probability distribution associated with each factor and a simulation to determine the probability distribution of the possible outcomes.

The best guess analysis indicates a net present value of $1,130,000, whereas the risk analysis shows that the most likely combination of events gives the project an expected net present value of only $252,000. The conventional technique fails to take into account the skewed distributions of the various factors and the interactions between the factors, and is influenced by the subjective aspects of best guesses. Furthermore, the conventional analysis gives no indication that this investment has a 48 per cent chance of losing money. Knowledge of this fact could greatly affect the decision made on this proposal, particularly if the investor is conservative and has less risky alternatives available.

The risk analysis technique can also be used for a sensitivity analysis. The purpose of a sensitivity analysis to determine the influence of each factor on the outcome, and, thus, to identify the factors most critical in the investment decision because of their high leverage, high uncertainty, or both. In a sensitivity analysis, equally likely variations in the values of each factor are made systematically to determine their effect on the outcome, or net present value. Table 1 shows the effect of individually varying each input factor (several of which are components of the net cash inflow).

This analysis indicates that manufacturing cost is a highly critical factor both in leverage and uncertainty. Knowing this, management may concentrate its efforts on reducing manufacturing costs or at least reducing the uncertainty in these costs.

Risk analysis is rapidly becoming an

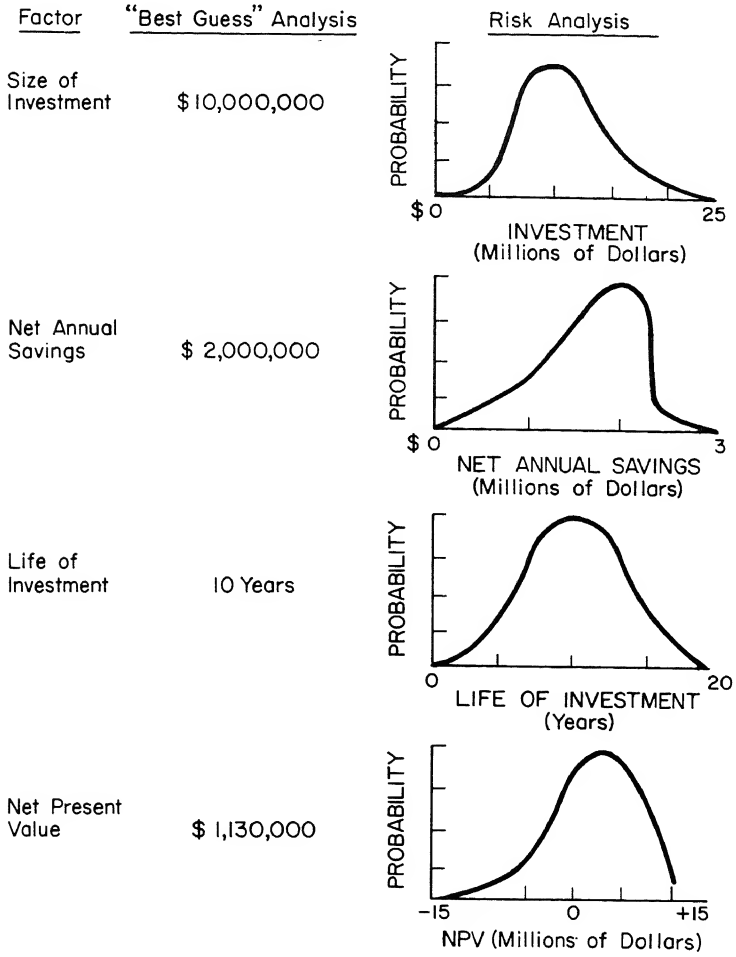


Figure 1

Two analyses of an investment proposal

established technique in American industry. Several large corporations are now using various forms of the technique as a regular part of their investment analysis procedure (1, 3, 7, 17, 18). A backlog of experience is being built up on the use of the technique, and advances in the state of the art are continually being made by users. For example, methods have been devised for representing complex interrelationships among factors. Improvements are also being made in the methods of gathering subjective probability estimates, and better methods are being devised for performing sensitivity analysis.

One aspect of investment decisions still eludes the capabilities of this technique. This is the problem of sequential decision making—that is, the analysis of a number of highly interrelated investment decisions occurring at different points in time. Until now no extension of risk analysis has been developed that can handle this problem well.

TABLE 1

Use of Sensitivity Analysis to Highlight Critical Factors

An Unfavorable Change of 10 Percentiles from the Mean Value in This Factor	*Which Corresponds to a Percentage Change of*	*Would Reduce NPV by*
Annual net cash flow		
Sales level	12	17
Selling price	10	21
Manufacturing cost	18	58
Fixed cost	4	6
Amount of investment	5	12
Life of investment	12	30

A Review of Decision Trees

The decision tree approach, a technique very similar to dynamic programming, is a convenient method for representing and analyzing a series of investment decisions to be made over time (see Figure 2). Each decision point is represented by a numbered square at a fork or node in the decision tree. Each branch extending from a fork represents one of the alternatives that can be chosen at this decision point. At the first decision point the two alternatives in the example shown in Figure 2 are "introduce product nationally" and "introduce product regionally." (It is assumed at this point that the decision has already been made to introduce the product in *some* way.)

In addition to representing management decision points, decision trees represent chance events. The forks in the tree where chance events influence the outcome are indicated by circles. The chance event forks or nodes in the example represent the various levels of

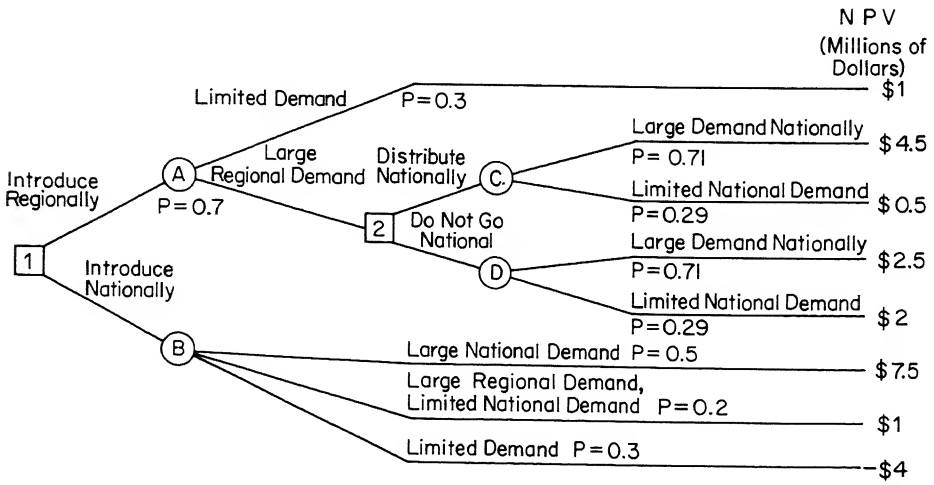


Figure 2

Use of decision tree to analyze investment alternatives for a new product introduction

demand that may appear for the product.

A node representing a chance event generally has a probability associated with each of the branches emanating from that node. This probability is the likelihood that the chance event will assume the value assigned to the particular branch. The total of such probabilities leading from a node must equal 1. In our example, the probability of achieving a large demand in the regional introduction of the product is 0.7, shown at the branch leading from node A. Each combination of decisions and chance events has some outcome (in this case, net present value, or NPV) associated with it.

The optimal sequence of decisions in a decision tree is found by starting at the right-hand side and "rolling backward." At each node, an expected NPV must be calculated. If the node is a chance event node, the expected NPV is calculated for *all* of the branches emanating from that node. If the node is a decision point, the expected NPV is calculated for *each* branch emanating from that node, and the highest is selected. In either case, the expected NPV of that node is carried back to the next chance event or decision point by multiplying it by the probabilities associated with branches that it travels over.

Thus in Figure 2 the *expected* NPV of all branches emanating from chance event node C is \$3.05 million (\$4.5 × .71 + \$−0.5 × .29). Similarly the expected NPV at node D is \$2.355 million. Now "rolling back" to the next node—decision point 2—it can be seen that the alternative with the highest NPV is "distribute nationally," with an NPV of \$3.05 million. This means that, if the decision maker is ever confronted with the decision at node 2, he will choose to distribute nationally, and will expect an NPV of \$3.05 million. In all further analysis he can ignore the other decision branch emanating from node 2 and all nodes and branches that it may lead to.

To perform further analysis, it is now necessary to carry this NPV backward in the tree. The branches emanating

TABLE 2

Net Present Value of Investment Alternatives for a New Product Introduction

Alternative	*Chance Event*	*Probability of Chance Event*	*Net Present Value*	*Expected NPV*
Introduce product nationally	Large national demand	.5	\$7.5	*\$2.75*
	Large regional, limited national demand	.2	1.0	
	Limited demand	.3	−4.0	
Introduce product regionally (and distribute nationally if regional demand is large)	Large national demand	.5	4.5	*2.44*
	Large regional, limited national demand	.2	−0.5	
	Limited demand	.3	1.0	
Introduce product regionally (and do *not* distribute nationally)	Large national demand	.5	2.5	*1.95*
	Large regional, limited national demand	.2	2.0	
	Limited demand	.3	1.0	

from chance event node A have an overall expected NPV of $2.435 million ($1×0.3+$3.05×0.7). Similarly, the expected NPV at node B is $2.75 million. These computations, summarized in Table 2 show that the alternative that maximizes expected NPV of the entire decision tree is "introduce nationally" at decision point 1. (Note that in this particular case there are *no* subsequent decisions to be made.)

One drawback of the decision tree approach is that computations can quickly become unwieldy. The number

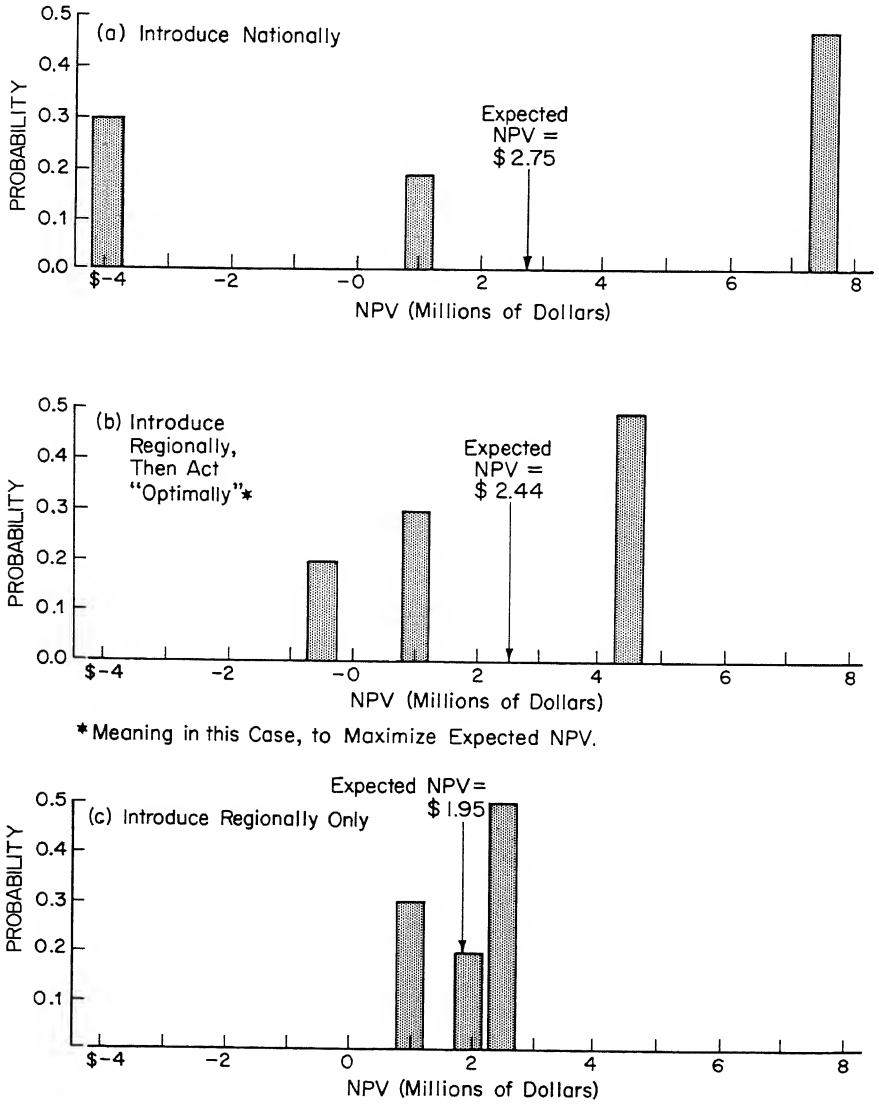


Figure 3

Range of possible outcomes for each of three alternatives

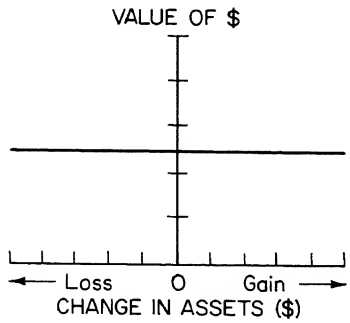
of end points on the decision tree increases very rapidly as the number of decision points or chance events increases. To make this approach practical, it is necessary to limit the number of branches emanating from chance event nodes to a very small number. This means that the probability distribution of chance events at each node must be represented by a very few point estimates.

As a result, the answers obtained from a decision tree analysis are often inadequate. The single answer obtained (say, net present value) is usually close to the expectation of the probability distribution of all possible NPV's. However, it may vary somewhat from the expected NPV, depending on how the point estimates were selected from the underlying distributions and on the sensitivity of the NPV to this selection process. Furthermore, the decision tree approach gives *no* information on the range of possible outcomes from the investment or the probabilities associated with those outcomes. This can be a serious drawback.

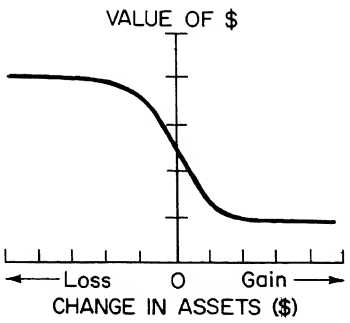
In the example in Figure 2 and Table 2, the decision tree approach indicated that introducing the product nationally at once would be the optimal strategy for maximizing expected NPV. However, the NPV of $2.75 million is simply the mean of three possible values of NPV, which are themselves representative of an entire range of possible values, as shown in Figure 3a. Comparing the range of NPV's possible under each possible set of decisions shows a vastly different view of the outcome. (See Figures 3b and 3c.)

Although the first alternative has the highest expected NPV, a rational manager could easily prefer one of the other two. The choice would depend on the utility function or the aversion to risk of the manager or his organization. A manager with a linear utility function would choose the first alternative, as shown in Figure 4a. However, it is probably true that *most* managers would *not* choose the first alternative because of the high chance of loss and the higher utility value that they would assign to a loss, as shown in Figure 4b. This conservatism in management is, to a large extent, the result of the system of rewards and punishments that exists in many large corporations today. Whether it is good or bad is a complex question, not discussed here.

In spite of these shortcomings, the decision tree approach is a very useful analytical tool. It is particularly useful for conceptualizing investment planning and for controlling and monitoring an



(a) Linear Utility Function



(b) More Typical Nonlinear Utility Function

Figure 4
Examples of utility functions

investment that stretches out over time. For these reasons, the decision tree approach has been, and will continue to be an important tool for the analysis of investment decisions.

Combining These Approaches: Stochastic Decision Trees

The complementary advantages and disadvantages of risk analysis and decision trees suggest that a new technique might be developed that would combine the good points of each and eliminate the disadvantages. The concept of stochastic decision trees, introduced in the remainder of this article, is intended to be such a combination.

The stochastic decision tree approach is similar to the conventional decision tree approach, except that it also has the following features:

1. All quantities and factors, including chance events, can be represented by continuous, empirical probability distributions.
2. The information about the results from any or all possible combinations of decisions made at sequential points in time can be obtained in a probabilistic form.
3. The probability distribution of possible results from any particular combination of decisions can be analyzed using the concepts of utility and risk.

A discussion of each of these features follows.

Replacement of Chance Event Nodes by Probability Distributions

The inclusion of probability distributions for the values associated with chance events is analogous to adding an arbitrarily large number of branches at each chance event node. In a conventional decision tree, the addition of a large number of branches can serve to represent any empirical probability distribution. Thus in the previous example, chance event node B can be made to approximate more closely the desired continuous probability distribution by increasing the number of branches, as shown in Figures 5a and 5b. However, this approach makes the tree very complex, and computation very quickly becomes burdensome or impractical. Therefore, two or three branches are usually used as a coarse approximation of the actual continuous probability distribution.

Since the stochastic decision tree is to be based on simulation, it is not necessary to add a great many branches at the chance event nodes. In fact, it is possible to reduce the number of branches at the chance event nodes to *one.* (See Figure 5c.) Thus, in effect, the chance event node can be *eliminated.* Instead, at the point where the chance event node occurred, a random selection is made on each iteration from the appropriate probabilistic economic model such as the break-even chart shown in Figure 6, and the value selected is used to calculate the NPV for that particular iteration. The single branch emanating from this simplified node then extends onward to the next management decision point or to the end of the tree. This results in a drastic streamlining of the decision tree as illustrated in Figure 7.

Replacement of All Specific Values by Probability Distributions

In a conventional decision tree, factors such as the size of the investment in a new plant facility are often assigned specific values. Usually these values are expressed as single numbers, even though these numbers are often not known with certainty.

If the values of these factors could

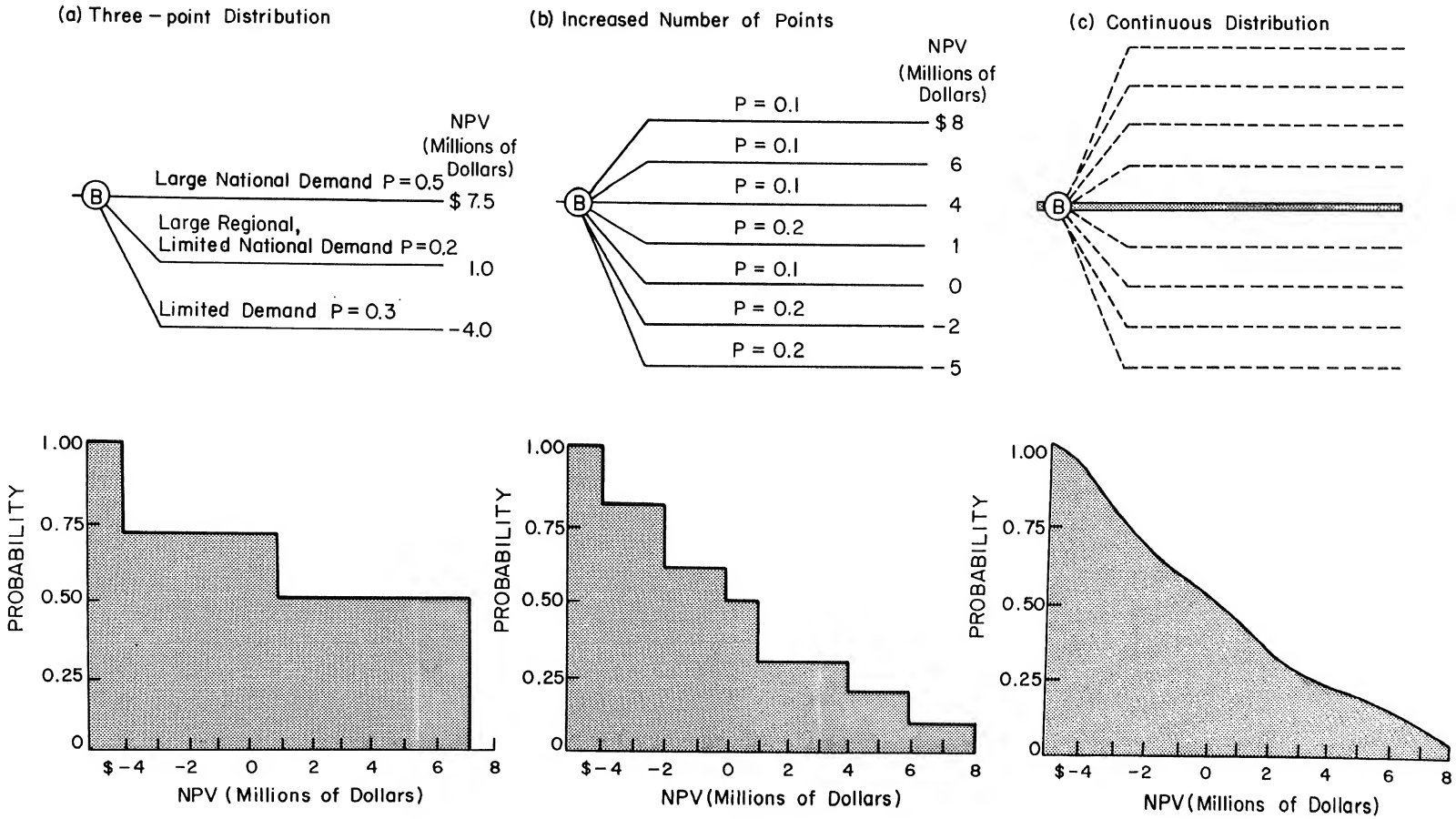


Figure 5

Probability distributions at chance event nodes

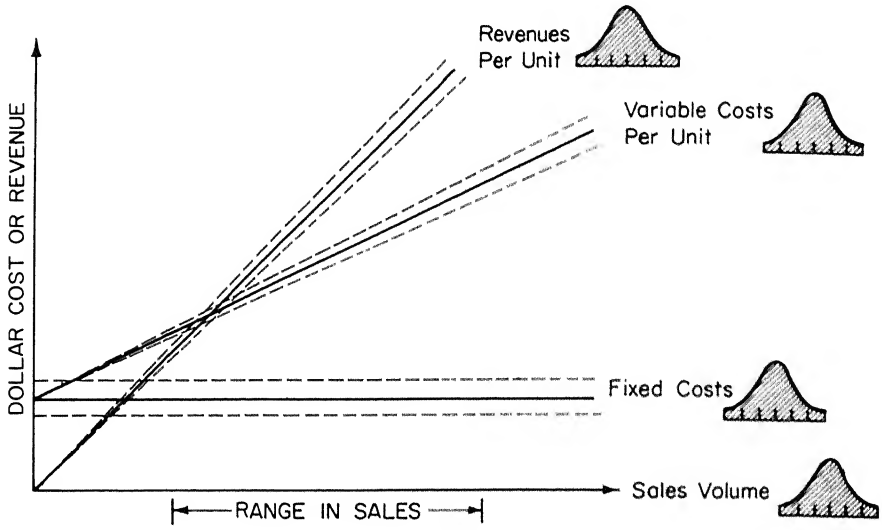


Figure 6

Typical probabilistic economic model used to select values of factors at chance event notes

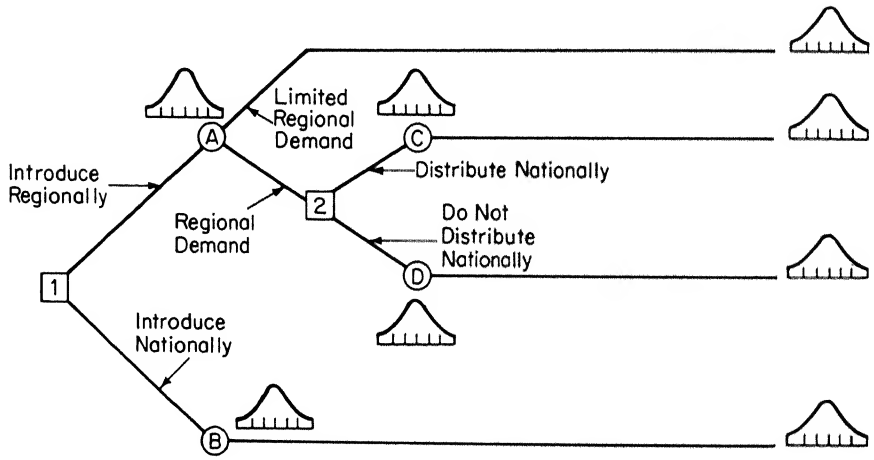


Figure 7

Simplified decision tree

be represented instead by probability distributions, the degree of uncertainty characterizing each value could be expressed. The stochastic decision tree approach makes it possible to do this. Since the approach is basically a simulation, any or all specific values in the investment analysis can be represented by probability distributions. On each iteration in the simulation, a value for each factor is randomly selected from the appropriate frequency distribution and used in the computation. Thus, in the example, NPV can be calculated from not only empirical distributions of demand, but also probabilistic estimates

of investment, cost, price, and other factors.

Evaluating All Possible Combinations of Decisions

Since this stochastic decision tree approach greatly simplifies the structure of the decision tree, it is often possible to evaluate by complete enumeration all of the possible paths through the tree. For example, if there are five sequential decisions in an analysis and each decision offers two alternatives, there are at most thirty-two possible paths through the decision tree. This number of paths is quite manageable computationally. And since most decision points are two-sided ("build" or "don't build," for example), or at worst have a very small number of alternatives, it is often feasible and convenient to evaluate all possible paths through a decision tree when the stochastic decision tree approach is used.

Why is it sometimes desirable to evaluate all possible paths through a decision tree? As the inquiry into the risk analysis approach showed, decisions cannot always be made correctly solely on the basis of a single expected value for each factor. The roll-back technique of the conventional decision tree necessarily deals only with expected values. It evaluates decisions (more exactly, sets of decisions) by comparing their expectations and selects the largest as the best, in all cases.

However, the stochastic decision tree approach produces *probabilistic* results for each possible set of decisions. These probability distributions, associated with each possible path through the decision tree, can be compared on the basis of their expectations alone, if this is considered to be sufficient. But alternative sets of decisions can *also* be evaluated by comparing the probability distributions associated with each set of decisions, in a manner exactly analogous to risk analysis. (The details of this technique are discussed in the next section.) Thus, the stochastic decision tree approach makes it possible to evaluate a series of interrelated decisions spread over time by the same kinds of risk and uncertainty criteria that one would use in a conventional risk analysis.

In a large decision tree problem, even with the simplifications afforded by the stochastic decision tree approach, complete enumeration of all possible paths through the tree could become computationally impractical, or the comparison of the probability distributions associated with all possible paths might be too laborious and costly.

In such a case, two simplifications are possible. First, a *modified* version of the roll-back technique might be used. This modified roll-back would take account of the probabilistic nature of the information being handled. Branches of the tree would be eliminated on the basis of dominance rather than simply expected value (7). For example, a branch could be eliminated if it had both a lower expected return and a higher variance than an alternative branch. A number of possible sets of decisions could be eliminated this way without being completely evaluated, leaving an efficient set of decision sequences to evaluate in more detail.

Computation could also be reduced by making decision rules before the simulation, such that if, on any iteration, the value of a chance event exceeds some criterion, the resulting decision would not be considered at all. This has been done in the example shown in Figure 2. If a limited demand appears at node A, national introduction of the product will not be evaluated. In the simulation, if demand were below some specified value, the simulation would not proceed to the decision point 2. This technique only saves com-

putation effort—it does not simplify the structure of the tree, and if the criterion is chosen properly, it will not affect the final outcome.

Recording Results in the Form of Probability Distributions

It has already been shown that probability distributions are more useful than single numbers as measures of the value of a particular set of decisions. The simulation approach to the analysis permits one to get these probability distributions relatively easily. It is true that the method smacks of brute force. However, the brute force required is entirely on the part of the computer and not at all on the part of the analyst.

The technique is simply this: On each iteration or path through the decision tree, when the computer encounters a binary decision point node, it is instructed to "split itself in two" and perform the appropriate calculations along *both* branches of the tree emanating from the decision node. (The same logic applies to a node with three or more branches emanating from it.) Thus, when the computer completes a single iteration, an NPV will have been calculated for each possible path through the decision tree. These NPV's are accumulated in separate probability distributions. This simulation concept is illustrated in Figure 8.

At the completion of a suitable number of iterations, there will be a probability distribution of the NPV associated with each set of decisions that it is possible to make in passing through the tree. These different sets of decisions can then be compared, one against the other, in the usual risk analysis matter, as if they were alternative investment decisions (which in fact they are). That is, they can be compared by taking into account not only the expected return, but also the shape of each probability distribution and the effects of utility and risk. On the basis of this, one can select the single best set of decisions, or a small number of possibly acceptable sets. These sets of sequential decisions can then be evaluated and a decision whether or not to undertake the investment can be made by comparing it to alternative investments elsewhere in the corporation or against alternative uses for the money.

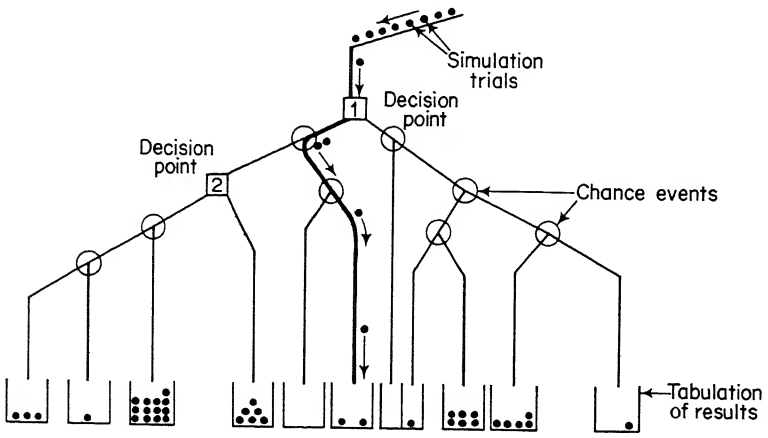


Figure 8

The GPSS concept of decision trees with risk simulation

An Example

To illustrate the kinds of results that can be expected from a stochastic decision tree analysis, the new product introduction problem described earlier has been solved using this method. The results are shown in Figure 9.

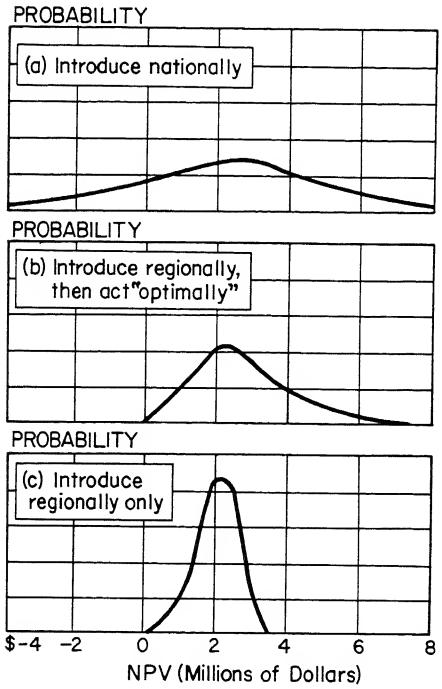


Figure 9

Results of stochastic decision tree analysis

The differences in the expected values of the outcomes can now be seen in proper perspective, since the results show the relationship of the expected values to the entire distribution of possible outcomes. Moreover, the expected values of these distributions will not necessarily be identical with expectations resulting from the conventional decision tree approach, because:

1. The interdependencies among the variables were not accounted for by the conventional approach.
2. The small number of point estimates used to approximate an entire distribution under the conventional approach did not utilize all the available information.

With the three alternatives presented in this form, it is easier to understand why a rational manager might choose an alternative other than the one with the highest expected value. Presented with the full range of possible outcomes related to each alternative, he can select that alternative most consistent with his personal utility and willingness to risk.

Using the Stochastic Decision Tree Approach

Stochastic decision trees described here combine the best features of both risk analysis and conventional decision trees and are actually simpler to construct and use than either of these. The steps for collecting data and conceptualizing the problem are the same for the stochastic decision tree approach as they are for the risk analysis approach. These steps are:

1. Gather subjective probability estimates of the appropriate factors affecting the investment.
2. Define and describe any significant interdependencies among factors.
3. Specify the probable timing of future sequential investment decisions to be made.
4. Specify the model to be used to evaluate the investment.

The stochastic decision tree approach is ideally suited to the computer language known as General Purpose Systems Simulator (GPSS) (5, 14). Although this language is not now capable of handling very complex interdependencies without certain modifica-

tions, it permits the solution of a very wide range of investment problems.

The structuring and solving of several sample problems have indicated that the stochastic decision tree approach is both easy to use and useful. The example in Table 2 and Figures 3 and 4 shows emphatically how the stochastic decision tree approach can detect and display the probable outcomes of an investment strategy that would be deemed optimal by the conventional decision tree approach, but that many managements would definitely regard as undesirable. Other work is being done on both sample problems and real-world problems, and on the development and standardization (to a limited extent) of the computer programs for performing this analysis.

Summary

The stochastic decision tree approach to analyzing investment decisions is an evolutionary improvement over previous methods of analyzing investments. It combines the advantages of several earlier approaches, eliminates several disadvantages, and is easier to apply.

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LIMIT DCF IN CAPITAL BUDGETING

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The failure of discounted cash flow methods to gain wider acceptance in industry may be because they do not incorporate the vital consideration of earnings to be reported to shareholders. The introduction of an earnings-growth constraint in a linear programming model allows a firm to choose a portfolio of projects which gives recognition to a minimal earnings growth rate deemed necessary to create increasing values for shareholders. The analytical merits, as well as possible conflicts, arising from the application of the model are discussed.

During the past ten or fifteen years businessmen have witnessed a constant stream of articles, speeches, and conferences urging their companies to adopt a discounted cash flow approach for making capital budgeting decisions. And at the same time, widespread educational programs have been carried on by business schools, trade associations, and consulting firms to explain the advantages of DCF. Despite all this activity, a recent study indicates that of 163 companies selected from the *Fortune* list of 500 companies, less than half employ the DCF approach.[1]

Many writers attribute the relatively slow acceptance of DCF to either (a) a lack of understanding or a feeling of futility about projecting cash flows more than a few years into the future or (b) a preference for payback bench marks on the part of risk-conscious decision makers with strong liquidity preferences.

For a given company, both of these factors may well discourage the use of DCF. But they do not tell the whole story. We believe that a third, largely overlooked reason for the failure of DCF to gain wider acceptance is that management has found DCF does not successfully come to grips with the vital consideration of what earnings the company reports to shareholders. If the application of a DCF criterion results in an erratic earnings pattern, and if managers prefer to have a pattern of orderly and sustained earnings growth which they can report, then it is reasonable to suggest that this combination of facts may account for some of the reluctance to adopt the DCF approach for capital budgeting decisions.

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[1] See Alexander A. Robichek and John G. McDonald, *Financial Management in Transition* (Menlo Park, Calif.: Stanford Research Institute, 1965), p. 7.

Adverse Effect on Prices

The importance of earnings per share (EPS) is generally linked by management to its broad objective of creating increasing value for the benefit of shareholders. In the survey referred to earlier, companies with multiple financial objectives were asked to rank the objectives in order of importance. EPS —in particular, its future level and/or growth rate—was indicated as the prime financial objective more often than was any alternative measure.

Let us suppose that a financial objective, such as maximizing the price of

TABLE 1

Estimated Cash Flows for Projects Under Consideration (in Hundreds of Dollars)

Project number	*Year*															
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1	$(239)	$ 45	$ 59	$ 64	$ 71	$ 70	$ 59									
2	(25)	(40)	(30)	(10)	20	70	100	$ 150	$150	$150	$100	$ 60				
3	(10)	(10)	(10)	20	30	50	40	20								
4		(120)	25	25	30	35	30	25	20	15	10	5				
5		(100)	(60)	(60)	80	74	66	56	44	30	14					
6		(20)	80	100	(10)	50	(100)	50	400	200						
7			(200)	(100)	0	50	200	300	200	50	50					
8			50	100	(200)	100	150									
9			(10)	50	100	(200)	(100)	100	300							
10				(80)	20	20	15	15	15	10	10	10				
11				(300)	(50)	200	300	400	200	0	100	100	$100			
12				(50)	200	150	(100)	(100)	100	200	150	100				
13					(300)	(50)	(100)	100	200	200	200	200	100			
14					(200)	10	80	100	300	500	300	200	(50)	$100	$100	$100
15					(100)	(50)	(50)	80	70	100	200	(50)	100	200	100	50

the corporation's shares, is the dominant organizing goal of a certain corporation, and that management uses reported growth in EPS to achieve its objective. How does adopting projects on the basis solely of DCF calculations affect the EPS the company reports to its shareholders?

To answer this question, we will assume that the corporate manager can solve all of the severe problems associated with the DCF method. This means, for example, that the company knows the appropriate cost-of-capital rate to use in discounting the cash flows of various projects, that the flows of various projects are known with certainty, and that the cash flows of each project are independent of the flows of the other projects. (None of these needs is easily met, as many financial executives know, and this fact alone weakens the case for the DCF approach.)

Investment Opportunities

Let us now suppose that this corporation is faced with the opportunity of investing in fifteen different projects over the forthcoming five years. The economic lives of these assumed capital investments range from five years to as long as twelve years. The estimated cash flows associated with each project are presented in Table 1.

Let us further suppose that the company under consideration employs a formalized profit-planning system with a five-year time span. The estimated income flows or profit contributions associated with each of these projects during the planning period are shown in Table 2. It is also estimated that the five-year income flows that will result if the company makes no additional investments are $10,000, $9,500, $9,000, $9,000, and $8,000, respectively. Earnings in year 0 were $7,350.

Note that the estimated annual income and cash flows shown for the projects in Tables 1 and 2 do not coincide in all cases; Project 1 and others have different flows. The divergence is due to the employment of the accrual accounting model for measuring the company's operating results. The possible relationships between income flows (revenue and expense) and

TABLE 2

Estimated Income Flows for Projects (in Hundreds of Dollars)

Project number	*Year*				
	1	*2*	*3*	*4*	*5*
1	$(20)	$ 5	$ 15	$ 30	$ 50
2	(25)	(40)	(30)	10	20
3	(40)	(30)	(20)	100	120
4		(50)	5	20	25
5		(100)	(60)	(60)	80
6		(20)	80	100	(10)
7			(50)	(30)	(20)
8			(80)	100	200
9			(10)	50	100
10				(80)	50
11				(100)	(200)
12				(50)	200
13					(10)
14					(200)
15					(100)

cash flows (receipts and disbursements) are summarized in Figure 1. To show how these estimated flows are derived for the fifteen projects, and also how the differences in income and cash flows arise, the detailed pro forma statements for Project 1 are presented in Table 3.

Selection of Projects

What projects will the company adopt if it uses the DCF approach and what earnings will the company report to its shareholders?

If the discount rate that the firm employs is k per cent per annum, then the net present value, V, of each project's net cash flows, a, over the next n years is found by the expression:

$$v = \sum_{t=1}^{n} \left[\frac{a_t}{(1+k)^t} \right]$$

In our case example, we assume that the manager of the company knows that the value of k is 20 per cent. Hence we can calculate the present value of each of the fifteen projects. These present values are listed in Table 4. If all of the projects that yield positive present values are purchased, the company will invest in ten projects and reject five. The present value of all of the projects purchased will be $97,513, and the earnings that the company will report to its shareholders over the next five years will be:

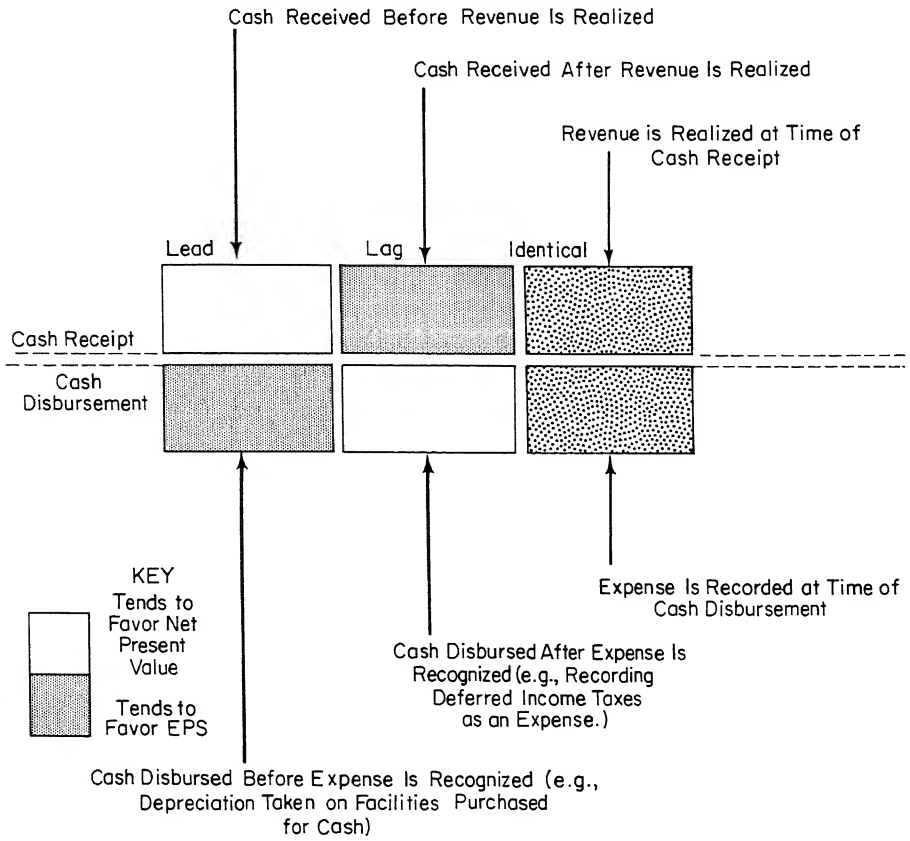


Figure 1

Possible relationships between cash flows and income flows

TABLE 3

Calculation of Cash Flows and Income Flows for Project 1 (in Hundreds of Dollars)

Project description—expansion of machine capacity
Estimated investment cost—$280
Estimated economic life—7 years
Depreciation method—sum-of-the-years' digits

	Year						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Cash receipts*	$ 21	$70	$104	$124	$151	$160	$139
Cash disbursements	280	20	30	30	30	40	40
	(259)	50	74	94	121	120	99
Federal income tax (50 per cent of income)	(20)	5	15	30	50	50	40
Net cash flow	$(239)	$45	$ 59	$ 64	$ 71	$ 70	$ 59
Revenue	$ 30	$90	$110	$130	$160	$160	$130
Depreciation	$ 70	$60	$ 50	$ 40	$ 30	$ 20	$ 10
Other operating expenses	0	20	30	30	30	40	40
	$ 70	$80	$ 80	$ 70	$ 60	$ 60	$ 50
Net income before tax	(40)	10	30	60	100	100	80
Federal income tax (50 per cent of income)	(20)	5	15	30	50	50	40
Net income	$(20)	$ 5	$ 15	$ 30	$ 50	$ 50	$ 40

* 70 per cent of revenue collected in year of sales; 30 per cent during the following year.

TABLE 4

Net Present Values of 15 Projects (in Hundreds of dollars)

Project Number	*Net Present Value*
1	$(35.75)
2	96.89
3	33.20
4	(10.67)
5	(29.82)
6	187.41
7	31.95
8	72.14
9	45.07
10	(9.21)
11	151.76
12	138.42
13	(12.19)
14	185.45
15	32.84

Year	*Earnings*
1	$ 3,500
2	500
3	−2,000
4	27,000
5	19,000
	$48,000

If reported earnings to shareholders have a bearing on efforts to maximize share prices, and if a target of sustainable and orderly growth in earnings is established, then the foregoing figures show that the DCF method leaves something to be desired. Surely the decline in earnings in Year 2 and the deficit reported in Year 3 will be viewed by the investment community at large as a failure of management to "use modern management tools to plan for contingencies." The dramatic rise in

earnings in Year 4, followed by a decline in Year 5, will give rise to the speculation that the company is subject to severe cyclical swings. But whether it is believed that management fails to plan or that the company is subject to cyclical swings, investors are likely to respond by placing a low multiple on the reported earnings. Hence share prices may be lower than they would be under another earnings pattern.

Better Approach

Let us now suppose that the corporate manager takes a different approach to the set of investment opportunities just described. Instead of adopting all of the projects that have a positive present value, he strives to maximize the present value of the investment projects *subject to the constraint that the earnings of the company must grow at a stipulated rate.*

If the stipulated growth rate is set at, let us say, 5 per cent per year, the manager would choose the ten projects indicated in Table 5. Some of these, it will be noted, are not completely adopted; for instance, only 89.75 per cent of Project 6 is adopted. In cases of this type we assume that the scope of the project can be reduced or, perhaps, that spending can proceed at a slower rate during the five-year period. If this is not the case, the project may be dropped completely, or perhaps adopted completely with an adjustment made either in another investment or in the earnings target. If management wants a list of projects which are adopted completely or rejected completely, it can have the selection made through the use of a method known as integer programming.

(The mathematical statement of the new approach is shown in Table 6. Here we do not consider the question

TABLE 5

Projects Adopted in Order to Assure a Growth Rate of 5 Per Cent per Year or More

Project Number	*Proportion Adopted*
1	100.00%
2	—
3	16.25
4	—
5	—
6	89.75
7	5.03
8	100.00
9	100.00
10	74.15
11	100.00
12	100.00
13	—
14	100.00
15	100.00

TABLE 6

Mathematical Statement of Approach Maximixing Present Value Subject to an Earnings-Growth Constraint

$$\text{Maximize} \sum_{j=1}^{15} \sum_{t=1}^{16} \frac{a_{jt}}{(1+k)^t} x_j$$

subject to:

$$\sum_{j=1}^{15} E_{jt} X_j - (1+g) \sum_{j=1}^{15} E_{j,t-1} x_j \geq 0,$$
$$\text{for } t = 1, 2, \ldots, 5$$
$$x_j + q_j = 1, \text{ for } j = 1, 2, \ldots, 15$$
$$x_j, q_j \geq 0$$

where a_{jt} represents the net cash flow of the j^{th} project in period t, x_j represents the proportion of the j^{th} project that is adopted q_j represents the proportion that is not adopted, E_{jt} represents the earnings of the j^{th} project in period t, and g represents the earnings-growth rate.

In this statement we ignore capital, labor, production, and other similar constraints because we wish to focus only on the relationship between earnings growth and the net present value of cash flows. Other constraints could, of course, be included if desired.

of what is the proper relationship between g, the growth rate, and k, the discount rate used to compute the present value of the cash flows; we assume that the rates are independent during the planning period.)

If we go back to Table 4 and find the present values of the ten projects adopted in whole or in part under the new approach, the total net present value is $71,800. This, of course, is well under the figure of $97,513 for the projects that would be chosen if the DCF approach were used. On the other hand, the new approach leads to a marked improvement in the consistency of reported earnings to shareholders during the five-year planning period. (Also, total earnings during the period are somewhat better.) The earnings are as follows:

Year	*Earnings*
1	$ 7,350
2	7,717
3	8,103
4	16,517
5	17,659
	$57,346

New Choices and Results

Examining the new list of projects in Table 5, we find several interesting variations from the set that would be adopted if the DCF approach were used:

1. Observe that the list includes the complete adoption of Project 1 and 74.15 per cent adoption of Project 10, both of which have negative net present values for their whole project lives (see Table 4). The reason for their inclusion is that they enable the company to report relatively large earnings during the five-year planning period.
2. Projects 11, 14, and 15, which have negative earnings during the five-year planning period, are adopted. The reason for this is that their cash flows beyond the planning period are large enough to increase the present values of the portfolio of accepted projects, and yet they can be included without violating the earnings constraint.

Note that the earnings of the company increase each year at a rate equal to or greater than 5 per cent per annum. Thus, rather than being considered by investors as a poorly managed or cyclical company, the company may now be viewed by the investment community as one that is capable of maintaining orderly and sustainable growth. As a consequence, a high multiple may be placed on the earnings stream.

The company can, of course, experiment with other feasible earnings-growth rates to test their impact on both the earnings stream over the five-year planning period and the aggregate net present values of the fifteen projects.

Conclusion

The familiar present value approach to capital budgeting requires that the projects with the highest present values be adopted first, and that projects which lower the present value of the company not be adopted at all. The imposition of an earnings-growth constraint changes the approach to capital budgeting in two important ways:

1. It makes income flows as well as cash flows relevant to the investment decision. It therefore results in a portfolio of accepted projects that has a lower present value than the unconstrained method allowed.
2. More important, it raises a policy question of what planning horizon the corporation should use in preparing its capital budget.

Recall that under the new approach, income flows are considered only for the length of the company's formal

profit-planning period. In our example, this was five years. The DCF calculations spanned a longer time period, up to twelve years. All present-value models are aimed at creating increasing values for the shareholder over some time span. The introduction of an earnings-growth constraint emphasizes performance measured by reported earnings over a chosen profit-planning period, whereas the unconstrained DCF model considers the performance over the estimated economic life of the portfolio of projects. If we eliminate, for practical reasons, alternatives to the present accrual accounting system used for public reporting, then an important aspect of the capital budgeting problem is balancing short-run and long-run considerations.

Short-run versus Long-Run

We do not propose a solution to the policy question of what time horizon a company should use for its capital budgeting planning period. At one extreme, management may adopt the position that market valuation based largely on investors' earnings expectations during a limited time period is economically unsound. Hence management may ignore interim market consequences in its pursuit of maximum long-run wealth. At the other extreme, management's strategy may be to create favorable market valuations during the short-run profit-planning period. Neither alternative is sound.

Total disregard for short-run considerations could create adverse effects on both the price of the company's shares and its ability to exploit actual investment opportunities when they arise in the future. The reason for this is that companies whose earnings and share prices are subject to violent swings may be thought of as being poorly managed, unreliable, or speculative. Such a reaction could adversely affect the market for the company's products, the terms on which suppliers will deal with it, the rate which it must pay in the capital markets, and other significant conditions.

At the other extreme, a strategy of creating favorable market valuations during a limited profit-planning period can also be unwise. The indiscriminate use of an earnings-growth constraint can lead to a serious questioning of management's economic wisdom, and perhaps also its standards of ethical behavior. The difficulty with an earnings-growth constraint in capital budgeting is highlighted by our example. The constraint may dictate that a company deliberately bypass some of its better opportunities for investment. For a corporation to "manage" its earnings in this fashion, and thereby deceive shareholders about real conditions and potentials, is to engage in a questionable practice. It is true that if a company has rising investment opportunities in prospect, it will be able to report higher earnings in succeeding time periods, and the price/earnings ratio will also likely become higher. But the reporting of higher earnings does not guarantee that the company has a series of increasing investment opportunities to exploit.

Undoubtedly, most managements would recognize the wisdom of a mid-course between the two extremes just presented.

We do not propose a solution to the question of what time horizon a company should adopt, or of the price management should pay for the company's reported earnings growth. However, the new approach we have described does allow management to deal explicitly with these questions. By contrast, the familiar DCF approach does not help management to come to grips with the issues raised. This is one of the reasons that the DCF approach has not gained wider acceptance in the financial community.

Editorial Comment for Chapter 7

No more challenging nor strategic decision is made by business executives than the capital budgeting decision. It is challenging because it involves a commitment of vast sums of money for which the resulting returns vary in degrees of uncertainty. And it is strategic since it will in large measure determine not only the economic vitality of the firm but also the enjoyment by society of the benefits of improved productivity and technology.

Solomon argues that "theoretically correct" capital budgeting models (i.e., discounted cash flow models) are of limited practical value because of the uncertainty involved in cash flow estimates. Since project rankings based upon DCF measures are so sensitive to estimating errors, he contends that project evaluation by simpler (sometimes simpler-minded) models, such as payback, may provide comparable results. Solomon attempts to illustrate these points with a simple sensitivity analysis. Both his method and scope of analysis, however, are convincingly challenged in Swalm's critique of this sensitivity study.

In any discussion of model performance, it is useful to distinguish between the structure of the model and the required data inputs. Ideally, we would like a model structure that properly reflects organizational decision criteria and data inputs that generate an output that can be meaningfully considered by the decision maker. A gross violation of either or both of these conditions can seriously jeopardize the usefulness of a given model. This leads us to a reconsideration of the Solomon argument. It seems defeating to suggest that since data inputs are surrounded by uncertainty, we reject "theoretically correct" models in favor of model structures (e.g., payback) that are less compatible with organizational objectives. Such an approach can only compound the problem, since we now have not only uncertain data but a questionable model structure as well. Given a "theoretically correct" model, a more positive approach is to improve the quality of the data within the context of that model. This is the approach taken by Hespos and Strassmann in their discussion of stochastic decision trees.

Before discussing the Hespos and Strassmann reading, one additional point concerning model structure should be noted. Assuming that reasonable input data are available, model simplification is warranted only if the outputs of the simpler model closely parallel the outputs of the "theoretically correct" model over a wide range of possible conditions. Consider, for example, the case of the payback reciprocal. Under certain conditions it can serve as a reasonable approximation

of a project's discounted cash flow rate of return. However, these conditions are limited (projects must have relatively long economic lives—at least twice the payback period—and fairly stable cash flows), and hence, the use of the payback reciprocal as a surrogate for DCF rates of return should be highly selective.

Procedures for handling uncertainty in capital investment analysis range over a wide spectrum of relative sophistication.[1] At one extreme, we find the still prevalent deterministic analyses where "certainty assumption" manifests itself in single-value "best estimates" for each relevant variable. Although it is generally recognized that these estimates represent averages with varying reliabilities, the lighter data demands of deterministic models no doubt contribute to their continuing popularity. Within the framework of deterministic capital investment analyses, a number of methods are used to cope with risk and uncertainty. One is to develop conservative forecasts for cash flows. A second method varies the minimum cutoff or discount rate according to the estimated degree of risk associated with different projects. Selective sensivity studies is still another method.

The principal limitation of a single estimate of a relevant variable is that no explicit recognition is given to the underlying probability distribution, that is, the possible range of estimates and the subjectve probabilities associated with each estimate within the range. Three-level estimates (optimistic, most likely, pessimistic) partially overcome the shortcomings of single forecasts, since the approximate range of possible results is portrayed. However, the executive's feelings about the probability of each of these estimates occurring is not made explicit. Once these probabilities are included in the analysis and additional estimates and associated probabilities within the range are specified, all the ingredients for a risk analysis are present.[2]

Risk analysis is applicable to projects characterized by great uncertainty, whereas the decision tree technique is particularly useful for analyzing a sequence of related decisions to be made over a period of time. Hespos and Strassmann's stochastic decision tree approach represents a promising means of simultaneously dealing with uncertainty and sequential decision making. It is important to emphasize that although risk analysis and the stochastic decision tree approach exhibit the shape of uncertainty, the choice among alternative projects is not always apparent. Depending upon the decision maker's utility function, the choice of the project with the highest expected net present value may or may not be dictated.

Recently, Hertz presented an interesting analysis for project choice under conditions of risk. His approach is based upon two fundamental propositions:

1. If two investment policies produce the same average return, the one that involves

[1] For a good summary see John R. Canada, "The Consideration of Risk and Uncertainty in Capital Investment Analyses," *Management International,* VII, No. 6 (1967).

[2] For a lucid exposition of risk analysis, see David B. Hertz, "Risk Analysis in Capital Investment," *Harvard Business Review,* XLII (January–February, 1964).

less "variability" (or uncertainty as to the outcome) is a more desirable or "efficient" policy.

2. Of two policies entailing the same variability, the one producing the higher average or "expected" return is the better policy. The expected return and the standard deviation (measure of variability) for each investment policy may be plotted on a graph as a means of determining the efficiency frontier, i.e., a curve that represents the best return a firm can expect to get for different levels of variability.[3]

The Lerner and Rappaport reading hypothesizes that the relatively slow acceptance of discounted cash flow models, even among the largest companies in the United States, is attributable to the fact that DCF models do not formally incorporate the consideration of earnings to be reported to shareholders. While this paper was intended primarily to develop certain insights into the proposed hypothesis, most of the financial executives who read it before its publication were interested in whether the model could be operationalized in their particular business. This represents, in the most informal sense, at least some modest evidence to support the hypothesis.

As is true of many models, the model presented in the Lerner and Rappaport reading is, in a large sense, a formalization of what management often does, albeit in an *ad hoc,* unstructured fashion. Why does management accept a project with a 15 per cent return rather than the alternative like-risk 20 per cent return project? If there is sufficient pressure to achieve certain near-term profit goals and the higher-return project is a significant burden on near-term profits, then one at least understands the reasoning for the choice of the 15 per cent project. Such a decision may be repeated a number of times for mutually exclusive alternatives. The proposed model differs only in that the decision is made systematically on the basis of formally specified goals and is achieved within the framework of a total portfolio of available opportunities. The model also requires that projects that will be available for consideration during the length of the profit-planning period be specified. This will of course be a particularly difficult requirement for firms with inadequate long-range planning systems.

Although no detailed discussion is proposed here, we have found the ethical implications of imposing an earnings-growth constraint an extremely provocative subject among businessmen and students alike. It raises the fundamental question: In whose interest is the corporation being run? Another central issue is the perennial debate over the proper balance between long-run and short-run considerations. One might even ask whether the basic problem resides in the accrual accounting measurement model which must somehow be reconciled with the economic present-value model.

[3] David B. Hertz, "Investment Policies that Pay Off," *Harvard Business Review,* XLIV (January–February, 1968), 103. Hertz's approach is an adaptation from Harry M. Markowitz, *Portfolio Selection: Efficient Diversification of Investments* (New York: John Wiley & Sons, Inc., 1959).

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8

Decentralized Financial Control Systems

RETURN ON INVESTMENT: THE RELATION OF BOOK-YIELD TO TRUE YIELD

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Using the internal rate-of-return variant of DCF, the relationship between it (true yield) and book yield and the ratio of book income to net book value of assets is examined. Variations in project life, capitalization policy, depreciation methods, timing of cash inflows, and investment growth rates are tested to establish the effect on the relationship between book yield and true yield. Implications of this relationship are discussed briefly.

This paper analyzes the relationship between the *book yield* on investment (measured as the ratio of net book income to net book value of assets) and the *true yield* on investment. It examines the effect on this relationship of variation in capitalization policy, depreciation methods, revenue patterns, and growth rates. It considers the implications of the potential error in the conventional book measure of rate of return for managerial evaluation and government regulation of private business.

The rate of return on investment is

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a key concept which is widely used for a number of significant business and financial purposes. It is of central importance for the evaluation of an individual investment project, the financial evaluation of a company's performance, the evaluation of managerial efficiency for a division or a product line and, finally, as a guide for establishing ceiling prices in the regulated industries.

The most commonly used multipurpose measure for return on investment is the ratio of net book income, as this is conventionally measured by the accounting process, to net book value of assets employed, similarly measured. The measure has several names such as "the accounting rate of return," "the book rate of return," "the conventional rate of return," but for the purpose of this paper we will refer to it as "book yield," defined here as follows:

$$a = \frac{F_t - D_t}{K_t} \qquad (1)$$

where

a = book yield in period t
F_t = funds flows from operations, before taxes, in period t
D_t = depreciation charges in period t
K_t = net book value of assets as of the beginning of period t
$F_t - D_t$ = reported before-tax operating profits in period t

One reason for the widespread use of the book yield as a measure of return on investment is that it ties in directly with the accounting process. A second and even more important reason is that it is the only approach available for measuring the ongoing return on investment for a collection of assets which together comprise a division or a company.

In spite of the wide use of the book yield ratio, surprisingly little work has been done on its validity and accuracy as a measure of rate of return. Does it correctly measure the actual yield on investment? Is it a consistent general yardstick in the sense that it provides comparable measures as between divisions, companies, and industries? These questions have been asked but they have not been answered systematically.

For at least one class of purposes for which return on investment is used, the book yield measure has been questioned and found wanting. I refer to single investment projects or acquisitions. In this situation the size and timing of all investment outlays and of all net cash receipts flowing from these outlays are available, or can be estimated either retrospectively or prospectively. Given these data, there is an alternative method available for measuring return on investment. This measure is the true or exact yield; i.e., that annual rate of discount at which the present value of investment outlays is just equal to the present value of cash receipts flowing from the investment.

This approach to the measurement of return on investment also has several names. In the financial world, where it is now universally used for the purpose of measuring bond yields, it is called "the effective yield to maturity." Economists have referred to it as "the marginal productivity of capital," "the marginal efficiency of capital," and the "internal rate of return." In the industrial world, where it is being used with increasing frequency to measure the rate of return on single investment projects it has been called, "the discounted cash flow method," the investor's method," the "scientific method," and the "profitability index." We will refer to it as "true yield."

The nature of the measure does not permit an explicit algebraic definition. However, for a single investment projest, in which input takes place at one point of time and output flows occur at annual intervals, the true yield r can be defined implicitly as the rate r which satisfies the following relationship:

$$I_o = \sum_{t=1}^{n} R_t(1+r)^{-t} \qquad (2)$$

where

I_o = investment in year zero
R_t = net receipts arising out of project I_o received in period t
n = length of the investment's productive life.

For the special case in which the investment generates uniform receipts over the life of the project, equation 2 may be restated as:

$$R = I_o\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right] \qquad (3)$$

For single investment projects it is now well known that project book yield and project true yield may differ, and that the difference between the two measures can be quite large. It is also widely recognized and provable that the answer provided by the true yield method is the correct one and that it is the book yield measure which is in error. Because of this the financial world long ago abandoned the book yield measure in favor of the true yield approach as a measure of bond yields. A similar move is now going on in the industrial world as far as single project analysis is concerned.

In contrast to the single project situation, a company or division is a collection of ongoing projects, and we have neither data nor estimates of all cash flows, past and future, associated with this collection of assets. Hence, we have no direct way of measuring or estimating the true yield for a company. In contrast, the book yield is conveniently available.

However, if the book yield approach produces incorrect results for a single investment outlay it must follow that the book yield measure for a company is also subject to error. The main purpose of the analysis which follows is to explore the size and nature of the potential error inherent in the book yield measure.

Methodology

Since it is not possible to get a direct measure of true yield for an ongoing company, it is not possible to check directly on the accuracy or error of the observable book yield measure.

What we can do is to develop hypothetical models of a company using a given true yield on investment and then test the book yield as it would appear from the *pro forma* income statements and balance sheets of such a company.

This is what is done in the models contained in this paper. All of them assume a hypothetical company that invests in a series of identical projects, each of which has an assumed true yield. The purpose of each test is to establish how the book yield measure differs from the known true yield when certain basic parameters are changed. The principal parameters are:

1. Length of project life
2. The timing and configuration of cash inflows relative to the timing of cash outlays
3. Accounting policy with respect to the capitalization and depreciation of investment outlays
4. The rate at which outlays grow over time

It is convenient to divide the overall analysis into two parts: (a) the static

or zero-growth situation in which a company's annual investment outlays are constant over time and (b) the dynamic situation in which the growth rate is something other than zero.

The Basic Zero-Growth Model

Assuming that all projects generate uniform and identical cash inflows per dollar of investment equal to R per period per project, then for any given period subsequent to n (if the investment process starts at period zero), we have:

$$a = \frac{2(nR - D)}{I(n+1)} \qquad (4)$$

nR = the total funds inflows from operations of all n projects operating in period t.

D = total depreciation expense during the period

$I(n+1)(\frac{1}{2})$ = net book value as of the beginning of period t:

$$K_t = \frac{I}{n}[n + (n-1) + \cdots + 2 + 1] = \frac{I(n+1)}{2}$$

For example, consider a company that acquires homogeneous investments each of which requires an outlay of $1,000 in year 0 and generates a cash flow of $229.61 a year for six years beginning exactly one year after the outlay is made.

The true yield on each investment is exactly 10 per cent per annum. The fact that it is 10 per cent and exactly 10 per cent can be easily demonstrated by placing a similar amount in a bank which pays 10 per cent interest on unwithdrawn balances, and by withdrawing $229.61 each year. The sixth withdrawal will exactly exhaust the balance. (See Table 1.)

Assume that the company in question acquires one such investment each year. Since each investment yields 10 per cent we know that the company's true yield must also be 10 per cent.

What would the book yield be for such a company? This depends of course on the depreciation method used, and on whether we use beginning-of-year, midyear or end-of-year net book value.

Using straight line depreciation and beginning-of-year net book values, it is easy to show that the company's net income will grow as it acquires new investments but that net income will settle at $377.66 from year 6 onward. The beginning-of-year net book value of assets will also rise as new investments are acquired, but this will also settle at $3,500 from year 6 onward. Thus from year 6 onward the book yield will stabilize at $377.66/$3,500.00 or 10.79 per cent. (See Table 2.)

In this particular instance the observable book yield overstates the true yield by some 8 per cent of the true yield, a not insignificant error. The error stems from the fact that, when cash inflows are level, the use of straight line depreciation reduces net book value at a faster rate than economic value declines.

If the basic characteristics of the model are held constant (i.e., if we continue to assume constant cash flows, no time lag between investment and the flow of benefits, complete capitalization of all investment outlays, and zero salvage at the end of each project's life), the error in the book yield changes with the duration of each underlying project. For example, for a 10 per cent true yield project which paid off in fifteen installments of $131.50 instead of six installments of $229.61, the observable book yield would be 12.16 per cent rather than 10.79 per cent. The error in the book yield measure rises as project life is lengthened. At the limit of very long life projects the

TABLE 1

Basic Model: Constant Cash Flows

Initial investment outlay $1,000 (all capitalized)
Constant cash flows for six years
Zero salvage value at the end of the sixth year
KNOWN TRUE YIELD of 10 per cent per annum.

Year	*Actual Investment of Year*	*Interest at 10 Per Cent*	*Balance at End of Year*	*Cash Withdrawal at End of Year*	*Ending Value*
1	$1,000.00	$100.00	$1,100.00	$229.61	$870.39
2	870.39	87.04	957.43	229.61	727.82
3	727.82	72.78	800.61	229.61	571.00
4	571.00	57.10	628.10	229.61	398.50
5	398.50	39.85	438.35	229.61	208.74
6	208.74	20.87	229.61	229.61	—

TABLE 2

Basic Model: Net Income, Net Book Value and Book Yields

Year	*Cash Flow*	*Depreciation (Straight Line)*	*Net Income*	*Beginning of the Year Net Book Value*	*Project Book Yield (Per Cent)*
Project: Single Investment of $1,000					
1	$ 229.61	$ 166.66	$ 62.95	$1,000.00	6.30
2	229.61	166.66	62.95	833.33	7.55
3	229.61	166.66	62.95	666.67	9.44
4	229.61	166.66	62.95	500.00	12.59
5	229.61	166.66	62.95	333.33	18.89
6	229.61	166.66	62.95	166.67	37.77
Project: Company's Successive Investment of $1,000 a Year*					
1	$ 229.61	$ 166.66	$ 62.95	$1,000.00	6.30
2	459.22	333.32	125.90	1,833.33	6.82
3	688.83	500.00	188.83	2,500.00	7.55
4	918.44	666.67	251.77	3,000.00	8.39
5	1,148.05	833.33	314.72	3,333.33	9.44
6	1,377.66	1,000.00	377.66	3,500.00	10.79
onward	1,377.66	1,000.00	377.66	3,500.00	10.79

* Company true yield—10 per cent; Company book yield—10.8 per cent.

observable book yield will approach twice the level of the known true yield. (See Table 3.)

Capitalization Policy

A second factor which has a major influence on the difference between the observable book yield and the true yield is accounting policy with respect to the capitalizing or expensing of initial investment outlays.

If the fraction c of each gross outlay is capitalized on the company's books, with the fraction $(1\text{-}c)$ being written

TABLE 3

Basic Model: Variation of Book Yield with Project Duration

Initial investment outlay $1,000 (all capitalized)
Constant cash flows
Zero salvage value at end of project life
KNOWN TRUE YIELD of 10 per cent per annum
Straight line depreciation

Project Life (Years)	*Annual Cash Flow (Dollars)*	*Annual Depreciation (Dollars)*	*Annual Net Income (Dollars)*	*Average Net Book Value (Dollars)*	*Average Apparent Rate (Per Annum)*	*True Yield (Per Annum)*
6	$229.6	$166.7	$ 62.9	$583.33	10.8	10.0
10	162.7	100.0	62.7	550.00	11.4	10.0
15	131.5	66.7	64.8	533.33	12.2	10.0
20	117.5	50.9	67.5	525.00	12.9	10.0
25	110.2	40.0	70.2	520.00	13.5	10.0
30	106.1	33.3	72.8	516.67	14.1	10.0
40	102.3	25.0	77.3	512.50	15.1	10.0
50	100.8	20.0	80.8	510.00	15.8	10.0
100	100.0	10.0	90.0	505.00	17.8	10.0
	100.0	0	100.0	500.00	20.0	10.0

off as expense during the current period, then the net book value would be accordingly reduced such that:

$$a = \frac{2(nR - I)}{cI(n + 1)} \qquad (5)$$

In the no-growth case, total annual deductions from net operating cash inflow nR remains equal to I, thus:

$$D = cI + (1 - c)I$$

where cI = depreciation expense for the period on capitalized investments, and $(1\text{-}c)I$ = portion of current investment charged off to expense.

For example, if we take the investment assumed in the basic model, i.e., a $1,000 outlay and $229.61 cash inflows for six periods, but introduce the assumption that $600 of the outlay is capitalized and $400 expensed in the first year, we get the following results. True yield (before taxes) remains at 10 per cent, but book yield (before taxes) rises to 17.9 per cent.

If we take the secondary effect of income taxes into account, the relationship between book yield and true yield again changes. For example, assuming a 50 per cent corporate income tax rate in the model just preceding, the true yield after taxes would be 6 per cent, and the book yield after taxes would be 9 per cent.

Depreciation Policy

A change in the rate at which book depreciation is taken will also change the relationship between the observable book yield and the true yield. On a before-tax basis the depreciation rate has no effect on true yield, but it does have a significant effect on observable book yield.

To illustrate this point, let us return to the basic full capitalization model, and replace the straight line deprecia-

tion used in it with the sum of years' digits depreciation schedule.

Total depreciation expense for each period is the same for both methods. Under the straight line method we have:

$$D = \frac{I}{n} + \frac{I}{n} + \cdots + \frac{I}{n} = I$$

and under the sum of years' digits method of depreciation, D is also equal to I.

$$D = \frac{nI}{\sum_{t=1}^{n} t} + \frac{(n-1)I}{\sum_{t=1}^{n} t} + \cdots + \frac{I}{\sum_{t=1}^{n} t}$$
$$= \left[\frac{I}{\sum_{t=1}^{n} t}\right]\left[\sum_{t=1}^{n} t\right]$$

In the zero-growth case, the real impact of the depreciation method is on the amount reported as net book value. Since relatively larger fractions of initial investment are written off early in a project's life, book values will be lower for more rapid depreciation methods than for the straight line calculation. For the sum of years' digits method, the net book value of all operating projects will be:

$$K_t = \frac{I\sum_{t=1}^{n} t}{\sum_{t=1}^{n} t} + \frac{I\sum_{t=1}^{n-1} t}{\sum_{t=1}^{n} t} + \cdots + \frac{I\sum_{t=1}^{2} t}{\sum_{t=1}^{n} t} + \frac{I}{\sum_{t=1}^{n} t}$$

This reduces to

$$K_t = \frac{I(n+2)}{3}$$

Hence, when the sum of years' digits depreciation is employed, the book yield is given by:

$$a = \frac{3(nR - I)}{I(n+2)} \qquad (6)$$

A change in the depreciation method used will leave the true yield (before tax) unchanged at 10 per cent. Net income will also remain unchanged at $377.66 for year 6 onward. (See Table 2.) But the net book value of assets will fall from $3,500 to $2,666.65. Thus the observable pre-tax book yield will rise from 10.8 per cent to 14.2 per cent.

Rising Cash Flows

A major variable which influences the size of the book measure relative to the true yield measure is the general timing of cash inflows relative to the timing of investment outlays.

A time lag between outlays and inflows can take one of three general forms: (a) The investment process itself may involve varying amounts of time. For example, the acquisition of a bond or a piece of equipment takes very little time. In contrast, the development of a producing oil well could involve a five-year lag between the inception of initial outlays and the time the project is complete. (b) There can be a lag between the completion of a project and the initial inflow of cash from operations. (c) The equivalent of a lag may exist when the inflows of cash are distributed over time in a rising pattern so that the bulk of the inflows occur further from the outlay point.

Assuming once again a total outlay of I, the effect of the first type of lag is to require larger cash receipts in order to maintain an effective true yield of 10 per cent. If the investment consists of instalments of P dollars per period over a total of $(m+1)$ periods before the project is finally operational, the true yield can be defined as:

$$\sum_{t=-m}^{0} P_t(1+r)^{-t} = \sum_{t=1}^{n} R_t(1+r)^{-t} \qquad (7)$$

It would be acceptable accounting practice to consider the total investment in this project as:

$$\sum_{t=-m}^{0} P_t = I.$$

But R would be greater here than was true in the basic model discussed above. For example, if the investment outlay for each project consists of two installments of \$500, one in year 1 and the other in year 0, the annual receipts required for each project to yield 10 per cent would be \$241.09. Using equation 4, the book yield is seen to be 11.16 per cent.

The second kind of lag occurs when, say, an investment made at the beginning of period 1 produces its first cash inflow at the end of period $(1 + p)$. In this case, true yield can be defined as:

$$I_o = \sum_{t=p+1}^{p+n} R_t(1 + r)^{-t}$$

$$R = I_o\left[\frac{r(1 + r)^{n+p}}{(1 + r)^n - 1}\right] \qquad (8)$$

if R is uniform over project life.

All the other elements required to find book yield would be the same as in the basic model if we assume, reasonably, that no depreciation is charged off until receipts take place. For example, if there is a lag of two years between the year of investment and the year of the first cash inflow (note that lag = 0 when investments produce a first receipt in year 1), book yield may be seen to be 12.13 per cent.

The third type of lag involves the configuration of cash receipts. A cash inflow pattern which rises over time will produce a higher book yield because the absolute size of dollar inflows generated by a project of given outlay and of given true yield are greater when inflows are delayed in time. If the cash inflows from each project rise logarithmically at the rate h, we have:

$$I_o = A\frac{(1 + h)}{(1 + r)} + A\frac{(1 + h)^2}{(1 + r)^2} + A\frac{(1 + h)^3}{(1 + r)^3} + \cdots + A\frac{(1 + h)^n}{(1 + r)^n}$$

(where A is some constant satisfying the above conditions), and hence we have:

$$a = \frac{A\sum_{t=1}^{n}(1 + h)^t - I}{K_t} \qquad (9)$$

If $r = 10$ per cent and $h = 12$ per cent, then cash flows from the project would be as follows:

Year	*Cash Inflows*
1	\$ 175.24
2	196.26
3	219.81
4	246.19
5	275.74
6	308.82
	\$1,422.06

After year 6, the total company cash flows will be \$1,422.06. From equations 1 or 9 it may be seen that the book yield is 12.06 per cent.

Conversely, it is possible to envisage an investment project which contains the opposite of this type of time lag, i.e., a project which offers large early returns that decline over time.

An example of such a project with r = 10 per cent and h = −12 per cent, would be:

Year	*Cash Inflows*
1	\$ 298.15
2	262.38
3	230.89
4	203.18
5	178.80
6	157.35
	\$1,330.75

The company book yield would then be 9.45 per cent.

To summarize, as far as the zero-growth case is concerned, the major findings are: (1) the book yield is not an accurate measure of true yield, (2) the error in the book yield is neither constant nor consistent. Indeed it is fairly capricious measure which may sometimes underestimate true yield, but which more generally overstates true yield.

The degree of potential overstatement ranges from slight under certain circumstances to very gross and misleading overstatements in others.

Specifically, the degree to which book yield overstates true yield is a complex function of four basic factors. These are: (a) Length of project life—the longer the project life, the greater the overstatement. (b) Capitalization policy—the smaller the fraction of total investment capitalized on the books, the greater will be the overstatement. At the limit for investments which are expensed 100 per cent, the observable book yield will rise toward infinity. (c) The rate at which depreciation is taken on the books—depreciation procedures faster than a straight line basis will result in higher book yields. At the limit the most rapid method of depreciation is, of course, tantamount to 100 per cent expensing of outlays and hence leads to the same result. (d) The greater the lag between investment outlays and the recoupment of these outlays from cash inflows, the greater the degree of overstatement.

Since no two investments and, hence, no two companies or industries are likely to hold investments that are identical with respect to all of these variables, it must follow that observable book yields do not provide a consistent measure of return on investment or even a consistent *ranking* of the underlying true yields actually being earned by such companies or industries.

Growth Situations

We now lift the assumption that the company's growth rate is zero, and we will find that the rate at which a division or a company or an industry acquires new investments is a major variable affecting the size of the error contained in the observable book yield.

So long as the investments being acquired are homogeneous, i.e., each year's investment produces the same true yield on that investment, it is easy to see that the rate at which investment outlays are made over time has no effect on the true yield being earned by the company as a whole. This will be equal to the true yield on each investment regardless of the rate at which investment outlays grow or decline over time.

However, the book yield is significantly affected by the pace at which investment outlays are made.

In order to see why this is the case it is useful to return to the basic model. In this model the $1,000 investment in year 1 produces a cash flow of $229.61 each year for six years. Using straight line depreciation, the depreciation allowance is $166.66 a year, leaving net income of $62.95 per year for six years.

Although annual net income is constant over the life of each investment, the net book value of assets employed is not constant. Rather, it declines steadily from year 1 until it reaches zero at the end of year 6.

This means that on a year-to-year basis the ratio of net income to net book value for each individual investment rises. In year 1 of the project's life the beginning of year net book value is $1,000 and, hence, the project book yield during year 1 is 6.3 per cent. (See Table 2.)

In the second year of the project's life it has a book yield of 7.5 per cent.

By the sixth year, the value of net book assets has fallen to $166, and the project's sixth year book yield is 37.8 per cent.

When a company acquires investments at a constant rate, the overall book yield for the company is simply the weighted average of the year-by-year project book yields, with the appropriate net book values used as weights. Thus in Table 2 the overall book yield of 10.8 per cent is equal to (6.3 per cent × 1,000 + 7.5 per cent × 833 + . . . + 37.77 per cent × 166.67) ÷ 3,500.

If, however, a company acquires new investments at a rising pace, the overall company yield in any year will be more heavily weighted with investment projects which are in their early phase of development and for which net book values are high relative to net income. Thus, the observable book yield for a growing company will be smaller than the observable yield for a nongrowing company, even though both hold essentially identical investments.

The opposite is true for a company which commits a smaller amount each year to new investments. For such a company the observable book yield is more heavily weighted with investment projects which are in their late phase of development and for which net book values are very low relative to net income. For such a company observable book yield will be higher than for a nongrowth company even though both companies hold identical investments.

In general, if the observable book yield is higher than true yield for a nongrowth situation, the introduction of positive growth will tend to lower book yield relative to true yield. The faster the growth, the more will book yield decline relative to true yield.

It is necessary to distinguish between two kinds of growth: (a) real growth in investment outlays (with no change in prices) and (b) money growth in investment outlays due entirely to inflation. Assuming a consistent true yield on each investment and a uniform rate of growth over time in investment outlays, it follows that net book value, cash receipts, depreciation expense, and the reserve for depreciation also grow at the rate at which investment outlays are growing.

Real Growth

When a company's real growth rate is g, book yield is given by:

$$a = g\left[\frac{(1+g)^n - 1}{1 + (1+g)^n(gn-1)}\right]\left[\frac{1 + (1+r)^n(rn-1)}{(1+r)^n - 1}\right] \quad (10)$$

This is derived from equation 1 and the following relationships; for $t = n$

$$F_n = I_o[1 + (1+g) + (1+g)^2 + \cdots + (1+g)^{n-1}]\cdot\left[\frac{r(1+r)}{(1+r)^n - 1}\right]$$

$$D_n = I_o\left[\frac{1}{n} + \frac{(1+g)}{n} + \frac{(1+g)^2}{n} + \cdots + \frac{(1+g)^{n-1}}{n}\right]$$

$$K_n = I_o\left[\frac{n}{n}(1+g)^{n-1} + \frac{(n-1)}{n}(1+g)^{n-2} + \cdots + \frac{2}{n}(1+g) + \frac{1}{n}\right]$$

If the book yield a is higher than the true yield r in the zero-growth case, then as g increases the book yield falls continuously toward r.

In the special situation where the growth rate just equals true yield, the book yield is also just equal to true yield.

In other words, when $g = r$, a is equal to r. The proof of this fundamental and important equality condition is as follows:

TABLE 4

Basic Model with Inflation

Real investment outlay $1,000 (all capitalized)
Constant real cash flows
Zero salvage at end of project life
KNOWN REAL TRUE YIELD at 10 per cent per annum
Money true yield 13.30 per cent
Inflation rate 3 per cent per annum
Straight line depreciation

Investments Made in Year	*Money Investment*	*Money Inflows in Year 6*	*Annual Depreciation Expense*	*Profits in Year 6*	*Net Book Value in Year 6*
0	$1,000.00	$ 274.18	$ 166.67	$107.51	$ 166.67
1	1,030.00	274.18	171.67	102.51	343.33
2	1,060.90	274.18	176.82	97.36	530.46
3	1,092.73	274.18	182.12	92.06	728.48
4	1,125.51	274.18	185.58	86.60	937.90
5	1,159.27	274.18	193.21	80.97	1,159.27
	$6,468.41	$1,645.08	$1,078.07	$567.01	$3,866.11

By definition,

$$aK_t = F_t - D_t \tag{11}$$

and

$$gK_t = I_t - D_t \tag{12}$$

Now, the condition $g = r$ exists only when all company receipts are reinvested, i.e., when $F_t = I_t$. In this case:

$$aK_t = gK_t.$$

Hence, if $g = r$, $a = g = r$.

It can also be seen directly from equation 10 that $a = r$ if $g = r$, regardless of n. Furthermore, it can be proved that as long as depreciation method, capitalization practice, time lags, and cash flow patterns are consistent over time, the growth rate of all items remains the same as the growth rate in investment, and the $r = g = a$ equality holds.

Inflationary Growth

The existence of inflation in the economy would directly alter the cash flow pattern from individual projects. Assuming for simplicity that inflation has an equal effect on the price level of investment input and cash flow output, we have:

$$I_o = \sum_{t=1}^{n} \frac{R_t(1+i)^t}{(1+m)^t} \tag{13}$$

where

m = money true yield
i = inflation rate
R = receipts in dollars of period zero.

On the basis of equation 2, equation 13 may be restated as:

$$I_o = \sum_{t=1}^{n} \frac{R_t(1+i)^t}{(1+i)^t(1+r)^t} \tag{14}$$

Thus we have money true yield $m = i + ri + r$.

Another way of looking at the effect of inflation is to say that all real cash receipts are multiplied by $(1+i)^t$ in order to obtain the actual cash inflow in period t. At the same time, actual investment, and, hence, depreciation

expense and net book value are themselves affected by the inflationary process. The various elements of equation 1 are therefore affected such that:

$$F_t = nI_o\left[\frac{r(1+r)^n(1+i)^t}{(1+r)^n-1}\right]$$

$$D_t = \frac{I_{t-n}}{n}[1+(1+i)+\cdots + (1+i)^n] = \left[\frac{I_o(1+i)^{t-n}}{n}\right]\left[\frac{(1+i)^n-1}{i}\right]$$

$$K_t = I_{t-n}\left[\frac{n}{n}(1+i)^{t-1} + \frac{(n-1)}{n}(1+i)^{t-2} + \cdots + \frac{1}{n}(1+i)^{t-n}\right]$$

which simplifies to

$$K_t = I_o\left[\frac{(1+i)^{t-n}}{ni^2}\right][1-(1+i)^n(1-ni)]$$

Thus, the book yield a may be computed, using equation 1, as follows:

$$a = \left[\frac{nr(1+r)^n}{(1+r)^n-1} - \frac{(1+i)^n-1}{ni(1+i)^n}\right]\left[\frac{ni^2(1+i)^n}{1-(1+i)^n(1-ni)}\right] \qquad (15)$$

Using the above equation, it can be seen that the introduction of a 3 per cent inflation rate in the basic model would produce a book yield of 14.7 per cent. (See also Table 4.)

Implications

If the findings above are valid, and there is no reason to believe that they are not, they present financial analysis with a serious dilemma. On the one hand, the ratio of net income to net book assets is not a reliable measure of return on investment. On the other hand, analysis definitely requires some measure of return on investment and there appears to be no other way in which this concept can be measured for an ongoing division or company.

The pragmatic answer is that book yield will continue to be used, but that its use must be tempered by a far greater degree of judgment and adjustment than we have employed in the past, and in extreme cases the measure may have to be abandoned altogether in favor of an alternative measure, such as the ratio of cash flow before depreciation to gross book value.

Adjustments are also required whenever book yields are used for the purpose of making interdivisional, intercompany, or interindustrial comparisons. While we have as yet no precise basis for making these necessary adjustments, the use of models does provide an approximate basis for doing so. It is probably better to use adjusted book yields even if the adjustments are imprecise than to use the unadjusted book yield figures, which we know are subject to error.

A final implication is that the conventional rate-base approach commonly used in rate regulation should be amended to take into account the fact that companies and industries differ widely with respect to the basic parameters that affect the accuracy of the book yield measure. For industry situations in which book yield is equal to true yield, multiplying an intended cost of capital rate by an original cost net book value rate base produces meaningful and intended results. However, for situations in which the book yield is higher than the true yield on invested funds, such a procedure will in fact provide a true yield significantly lower than the cost of capital rate being aimed at.

NEW SYSTEM FOR DIVISIONAL CONTROL

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A system of decentralized control for integrated, multidivisional companies is proposed. The system controls each profit center on the basis of three budgets: (1) a contribution budget, (2) a fixed- and managed-cost budget, and (3) a capital budget. The advantages of this system over conventional return-on-investment (ROI) systems are enumerated.

A large and growing number of U.S. corporations are evaluating the performance of divisions on the basis of return-on-investment (or ROI) calculations.[1] More and more, ROI has come to be the "approved" method for this purpose; certainly, it has received the blessing of many noted authorities in the management field.

In this article we want to challenge the prevailing view. It is our conviction that ROI for divisional performance evaluation can be so misleading that it is destructive. It provides information that logically leads to incorrect decisions. It motivates division managers to take actions contrary to the best interests of the company. And it provides top management with misleading information about divisional performance. ROI fails in these ways because it uses profit centers which cannot really be profit centers, transfer prices which are not really prices, and investment bases which are not in fact relevant.

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[1] See John J. Mauriel and Robert N. Anthony, "Misevaluation of Investment Center Performance," *Harvard Business Review* (March–April, 1966), 98.

Fortunately, there is an alternative approach which is quite workable and far more appropriate to the needs of top management—and of division managements—in multidivisional corporations. After analyzing the severe limitations of ROI as the basic system of management control, we will, therefore, outline the new system. The system is an improvement, in our opinion, because it holds division managers responsible only for what they can control, and it immediately signals variations in performance from expectations. The proposed system is based on a budget of the division's expected contribution to corporate profits for the coming year, on a fixed- and managed-cost budget, and on a capital budget.

It must be emphasized that this discussion applies to integrated, multidivisional companies. Our generalizations are not appropriate for small firms, companies without divisions, or companies with relatively independent, semiautonomous divisions whose performance is evaluated over a span of years. In such cases, ROI is not used for control purposes; transfer prices are not involved, and there is no problem of optimizing relations between different units.

Desired Specifications

Prior to World War II, the subject of this article would have been primarily of academic interest; the multi-

divisional conglomerate was rare. The integrated company tended to be run from the top on functional lines. Then General Motors demonstrated the value of divisionalization on product lines; Du Pont emphasized the importance of return on investment as a management concept, and General Electric dramatized the combination by breaking itself into nearly 100 semiautonomous profit centers and using ROI as the basis of corporate control.

These examples were widely emulated. Unfortunately, the concept was copied literally in many cases, without reference to the subtle side effects and by-products or the limitations. The consequences have been similar to those of a miscalibrated speedometer or compass. It either keeps one from performing as well as one can or leads him into serious trouble.

The need in a multidivisional company is for a financial management control system to replace the intimate, intuitive knowledge which is possible in a simpler company. Profit centers, ROI, and transfer prices were conceived to make it possible to deal with a complex organization by breaking it into a number of independent parts which can be regarded as if they were independent entities.

Of course, such an attempt cannot succeed fully in an integrated company. This is impossible, even theoretically, except in the purest of conglomerates. If there is integration, there is necessarily some gain or benefit by having the various operations integrated. The integrated performance should exceed the performance achieved when the two operations are kept separate. If it does not, why integrate? If it does, which profit center is to be awarded the benefits of the synergy?

Often the optimum results are achieved by restricting the performance of one division in order to achieve a net performance gain for the organization as a whole. Accordingly, if the profit centers are treated as truly autonomous, the potential gain from integration is sacrificed. If we place the corporate interest first, we must regard the profit-center concept as a dangerous fiction.

What is needed is an inclusive management control system. The purpose of such a system is to cause the best decisions to be made for the benefit of the corporation as a whole, whether or not those decisions are delegated to divisions. In short, the system should:

1. Provide relevant information to all managers at each point where a decision must be made
2. Provide a basis for evaluating management performance
3. Motivate each manager in such a way as to optimize total company performance

Failures of ROI

Why cannot these purposes be achieved by a management control system based on ROI and profit centers? One set of troubles has to do with the information produced by ROI calculations; another concerns the motivations stimulated by ROI. Let us examine each in turn, after first outlining some basic principles of transferring parts, components, and other material from one division to another.

Principles of Transfer

Profits are maximized when all management decisions are based on taking the action that optimizes the profit of the company as a whole. This is self-evident. But to make such decisions, it is necessary to know their effect on the company as a whole. This relevant information is simply the marginal con-

tribution, viz., the net change in value that results from a given action. More precisely still, marginal contribution is the difference between (1) the increase in income that the action would produce—what is technically called the marginal revenue—and (2) the increase in expense which would be produced—what is often called marginal cost.

By definition, company profits will be maximized when marginal contribution is maximized. Consequently, it is vital that a management control system provide approximations of marginal contribution to decision makers at each point where a decision must be made.

Where material is transferred between divisions, the marginal cost is either the market price of the material (less selling expense)—where a true market for the material exists—or the out-of-pocket cost of the additional production. It is the market price when a true market exists because this is the lost opportunity cost if it is not sold. In other words, the market price is the revenue which is given up by using the material in the corporation instead of selling it. If the material could not be sold, marginal cost is no more than the out-of-pocket cost of production because this is the expense incurred in order to use the material as desired.

This concept is very important in intracompany pricing. It means that market prices should be used as transfer prices only where there is an actual market which could absorb the amount of product in question at the transfer price agreed on. So-called "approximate" or "negotiated" transfer prices do not represent the marginal cost to the company if there is no alternative market in actual fact, because there is no opportunity cost; that is, no income is lost by keeping the material in the company. Consequently, all "approximate" or "negotiated" transfers will obscure the relevant costs from the decision maker, and any decision based on these costs will be optimum only by coincidence. Here is an example of this situation:

> A company manufactures and sells appliances. The manufacturing facilities are divided into profit centers by type of appliance produced (e.g., washers, dryers, refrigerators). All appliances are sold by a single marketing division. The finished appliances are transferred from the manufacturing divisions to the sales division at a negotiated transfer price based on a common formula—standard cost plus a profit on investment.
>
> The relevant costs from the company's view-point are the out-of-pocket costs of production; nothing else can matter much. Yet the manager of the marketing division bases his sales and pricing decisions on transfer prices which include fixed costs and negotiated divisional profits. (If the appliances are transferred to the sales division at market price less a negotiated sales discount, the situation is equally bad.)
>
> The selling division's marginal costs are so different from the company's costs that incorrect marketing decisions are actually encouraged. For instance, cranked into the selling division's costs are fixed plant and salary expenses from manufacturing divisions that the corporation would have to bear anyway—not marginal costs at all—and "paper profits" for those divisions that were worked out in conference, not in actual market transactions. These costs will probably be much higher than the out-of-pocket costs to the corporation of manufacturing more appliances and getting them to dealers.

Some people believe that marginal costs are important only as a means of knowing how far a price can be reduced, and that if prices are well above marginal costs, this is all one needs to know. Nothing could be further from the truth. Every market-

ing decision—price, product mix, sales promotion, and the rest—requires a knowledge of marginal costs in order to be made intelligently. As a result, any system that transfers goods or services between two company locations at anything other than marginal costs (when true markets do not exist) makes optimum decision making impossible.

Suppose true markets do, in fact, exist for the material being transferred. Then there is no benefit in integration unless it produces a value above market price. The effect of a truly fluid market is to uncouple the two operations; the divisions may then vary their volume and mix without regard to each other. If, however, there is what we call a "spot market"—that is, one which is temporary, restricted in area, or otherwise limited—contribution and marginal value are relevant to our discussion. They are the amount of value in excess of the available revenue from the spot market.

With the foregoing points in mind, let us turn to the ROI approach.

Misleading Information

ROI is a fraction, with annual net profit as the numerator and investment as the denominator. Both of these figures are so arbitrary that it is difficult to justify them as a measure of performance.

Net Profit. This is an accounting concept that is designed to match costs against revenues over the period of time being studied. The theory behind income determination is complex and not particularly significant to the problem at hand. It is sufficient here to note that there are many opinions and many theories on the proper allocation of costs to time periods and that there are significant disagreements among experts on how to do this. The accounted net profit for any year can be significantly affected by the type of depreciation used (e.g., straight line versus double declining balance) and by the estimated life of the investment. Furthermore, the net income can be affected by whether an item of expenditure is capitalized or treated as an expense.

Over long periods of time these differences in treatment cancel out. Expense may be deferred, but it will eventually be counted. Costs may be treated as current expense even though the benefits are long deferred. But, over a short period such as one or two years, the effect may be to make reported profit quite different from actual net. Worse still, the reported figure can be quite different for two managers with identical performances. Short-term profit performance is nearly meaningless unless it is coupled with deep insight into the eventual consequences of the costs being incurred.

Accountants have, of course, long recognized this situation. *They* must live with it because there is no adequate substitute in financial accounting. It is foolish, however, for any company to use such an admittedly arbitrary figure as reported profit in the evaluation of management performance when better information is available.

Investment. The problems of the investment base in ROI are even more severe than those of income determination. Many of these problems have been covered in previous HBR articles.[2] All of the difficulties boil down to the facts that:

1. The amount of investment is arbitrary

[2] See John Dearden, "Problem in Decentralized Profit Responsibility," *Harvard Business Review* (May–June, 1960), 79; and "Problem in Decentralized Financial Control," *Harvard Business Review* (May–June, 1961), 72.

in that expenditures which have residual values beyond the accounting period are not always capitalized (e.g., research, recruiting, organizational development, and patent costs).

2. The amount of investment is the net result of literally hundreds of decisions by different people that could go back many years. Any relation between original cost and current economic value is purely coincidental. The present economic usefulness of an investment depends on technology, markets, and many other factors. Neither the original cost nor the accounting residual value has any necessary relationship to economic value. Besides, assets can appreciate or depreciate in value or become obsolete.

Combined Effect. All in all, ROI is so imprecise that it presents more problems than it solves in measuring divisional performance. Both the numerator and the denominator of the fraction are subject to wide ranges of arbitrary decisions in determining the amount of investment, the amount of expense, and the method of converting investment into expense. Also, both the numerator and the denominator include an allocation of sunk costs having nothing to do with current operations. Indeed, even where all accountants agree on the policy of capitalization, it could be incorrect for measuring performance—as, for example:

1. Investments in a marketing organization and the development of customer loyalty are almost universally treated as expenses; yet in many companies these investments represent valuable assets.[3]
2. In divisional profit statements we frequently see huge rates of return being earned by divisions that are largely concerned with marketing, because they have a minute investment base.

[3] See Edward C. Bursk, "View Your Customers as Investments," *Harvard Business Review* (May–June, 1966), 91.

Misdirected Motivation

Motivation and evaluation are actually two sides of the same coin. That is, the division manager is motivated to optimize the factors on which he is being evaluated. If the measurement of performance is such that a manager can improve his performance by taking action that is contrary to the company's interests, he will be motivated to do so. In an ROI system the manager is motivated to take the action that optimizes his return on investment. This will not always be the action that is best for the company. For example:

In a highly profitable division of a multidivisional company, the purchasing agent requested permission to increase the inventory in order to take quantity discounts; the return on investment would have been 25 per cent on the inventory increase. His request was refused because the division was already earning 35 per cent on its book investment. Therefore, a 25 per cent investment would have averaged down the 35 per cent. Incidentally, the company as a whole was earning less than 10 per cent!

In many instances, the decision maker may not even *know* what the optimum decision is from the company's viewpoint. In other instances, if he does know and takes action to optimize company profits, his own reported performance may suffer. There are many occasions where the use of ROI will motivate the manager to take incorrect action. To illustrate:

A division manager can optimize his profits by spending money for advertising and sales promotion as long as more than $1.00 in contribution (revenue minus the out-of-pocket costs) is earned for each $1.00 spent. If his selling price is $1.00 and his internal transfer price plus variable added costs is $0.90, this will mean that each added sale will contribute $0.10. Consequently, he will advertise only as long as $1.00 of advertising produces at least

$10.00 in sales (assuming, of course, that he knows these figures and wants to maximize profits). From the *corporation's* point of view, however, this may be all wrong; the profit center approach may be making him too conservative. The corporation may be able to earn $1.00 for each $0.50 of out-of-pocket or marginal costs. From its standpoint, it would be better if the division manager keeps increasing advertising as long as $1.00 in advertising produces at least $2.00 in sales.

An analysis of a proposed investment for a division showed that it would return 15 per cent after taxes. In the next two years, however, the rate of return would be negative to the division because (a) declining balance depreciation reduced the accounted profits, and (b) the net book value of the investment was near the gross book value. Consequently, the division manager did not submit the investment proposal because he did not want to affect his ROI adversely in the next two years. However, the *company's* cost of capital was 10 per cent, and from its standpoint the investment was sound.

In order to increase his rate of return, a division manager reduced his research costs by eliminating all projects that did not have an expected payout within two years. He believed that if he did not improve his rate of return, he would be replaced.

A division manager scrapped some machinery that he was not currently using in order to reduce his investment. Later, when the machinery was needed, he purchased new equipment.

The foregoing are only a few of the examples that we could cite from experience to show how ROI causes division managers to make decisions which are not in the best interests of the corporation.

Proposed Solution

The concept of marginal cost in transfer pricing is at least ten years old.[4] Furthermore, the problems of profit and investment determination have been known for nearly this length of time. In spite of this, most of the largest companies in the United States continue to use ROI as their basic system of management control. Why?

One reason, we feel sure, is that most top managers realize only vaguely the severe limitations of the ROI system. When it is pointed out that the system motivates division managers to take action not in the company's best interests, there is still a tendency to believe managers "will always put company interests ahead of divisional interests." But anyone who has intimate contact with profit-center systems knows how false this belief can be.

Probably a more basic reason for persisting in the use of ROI is the belief that, imperfect though it may be, there is no substitute for it short of recentralization of decision-making responsibility. In other words, many businessmen believe that ROI and the decentralization of decision-making responsibility must go together, and that to abandon ROI means abandoning the decentralization of responsibility for performance. Nothing could be further from the truth.

We wish to propose a system of decentralized control that does not have the disadvantages of ROI. This system controls each profit center on the basis of three budgets:

1. A contribution budget
2. A fixed- and managed-cost budget
3. A capital budget

All transfers of goods and services between company units are reported at marginal costs, or at the best approximation of marginal costs that is practicable. This means that market

[4] See Jack Hirshleifer, "On the Economics of Transfer Pricing," *The Journal of Business* (July, 1956), 172.

prices will be used only when there is a real market that could absorb the product. When no such market exists, goods are transferred at standard marginal cost, which will be standard variable cost in most instances. In general, however, at least two prices will be needed—one at less than nominal capacity and the other at above nominal capacity. In some instances, several prices may be required if costs change significantly under various conditions.

Let us look at these features in more detail.

Contribution Budget

The basic device for controlling the month-to-month operation is the contribution budget. Each year, each division submits a budget of the expected contribution for the coming year. This budget consists of expected revenues minus the costs of doing business, i.e., variable costs. It is drawn up in sufficient detail to allow management to evaluate it. As will be explained later, it is closely tied into the managed-cost budget and the capital investment budget.

(Generally speaking, the costs of *being* in business, as opposed to doing business, will be included in the managed-cost budget. Although some flexibility with respect to defining fixed or managed manufacturing costs can be allowed, we find that a satisfactory definition of them is "those costs that would be incurred under shut-down conditions of from two to four weeks." Marketing costs that are incurred *after* the point of sale would be considered variable. However, all other marketing costs, as well as research and development and administration costs, would be considered managed costs. Incidentally, this system ties in very well to a standard direct costing system.)

Where all revenues are from inside sales which are priced on the basis of standard variable costs, the budgeted contribution will be zero. (This is true because the costs deducted, like the revenues, equal the variable costs.) It is very important to understand that under a marginal contribution budget system, a contribution of zero by a division that sells exclusively to other company divisions can represent just as effective performance as a large contribution to overhead and profits. The important comparison is the actual versus budgeted contribution, with the reasons for the difference.

There are two advantages to the "zero contribution budget":

1. Intracompany transfers can be made at amounts designed to approximate marginal costs without penalty or reward to the selling division as long as it can control its costs.
2. Divisions that have no opportunity to sell their products outside the company are not penalized for volumes lower than budget or rewarded for volumes higher than budget. This is important in performance evaluation because it is principally the divisions which sell outside the company that are responsible for the level of sales volume.

What about divisions which sell to outside customers (or can readily sell to outside customers)? They will also be evaluated on the basis of a marginal contribution budget. That budget for them is the potential outside revenue minus the variable costs of production. Note that because intracompany material is transferred at marginal value, the full impact on profits of changes in volume is assigned to the division responsible for the sale. Note also that absolute profits are meaningless in this system, as they should be. You cannot subtract the division's fixed and managed costs from its mar-

ginal contribution and obtain net profit because fixed costs of other divisions are not included.

One special situation should be considered here. Occasionally a true and fluid market exists for a division's output, even though it in fact normally sells within the company. The output of a division-owned oil well, coal mine, or tree farm would have a ready market whether or not the parent could further process that output. In this case, the potential revenue from the outside sale minus selling cost becomes the nominal value (marginal value) of the materials produced. This value is the transfer price. The assumption is made that this output could be sold outside (whether or not it is sold outside in fact). Under these conditions, there is no reason why the supplying division cannot operate at nominal capacity at all times. Therefore, its contribution budget is based on the nominal capacity output multiplied by the difference between the transfer price and its own marginal cost.

Other Budgets

Each year the divisions submit a managed-cost budget. This budget includes the fixed manufacturing costs, the marketing cost incurred before the point of sale, the research and development costs, and the administrative costs. (Note that only cash costs are included. Depreciation and other costs representing allocation of previous investments are excluded.)

It is advisable to divide the managed-cost budget into two parts:

1. *The costs required to maintain the present level of operation.*
2. *The costs of increasing, or the savings from decreasing, present levels of operation.* These are managed costs. They show, in many cases, future increases in contribution. When changes in the level of either managed or fixed costs are approved, the promised future increases in contribution are noted and included on the appropriate year's contribution budget. (We will come back to this point later.)

As for capital expenditures, the procedures for evaluating and approving them are well known and need not be considered here. The unique feature of the proposed system is that the cash flows on which a capital investment proposal is justified are included in the appropriate year's contribution budget. The important point about capital expenditures is the fact that they are a long-term commitment of corporate resources. As such they represent corporate policy decisions, since they commit the company to certain kinds of business. Almost by definition, they should not be authorized unless they have been analyzed in terms of the effect on the corporation as a whole over time. To this extent, investment decisions do not belong in the control system but in the policy planning system.

Integration and Interaction

The three budgets are tied together by including in each year's contribution budget the effect on contribution of the managed-cost budget and the capital investment budget. This can be done in the manner shown in Table 1. Columns 2 and 3 show the cumulative impact of the previous managed-cost budget levels on the contribution for the current year. Thus:

Assume that an increase in marketing costs was approved for the expansion of a product line in 1965. The justification for this added expenditure was an increase in contribution as follows:

TABLE 1

Example of Integrated Budget (in Thousands of Dollars)

	1966						
	Original (1)	*Plus Approved Expansion* (2)*	*Less Approved Contractions* (3)†	*Plus Effects of New Capital Investments* (4)‡	*Adjusted Budget* (5)§	*Proposed Budget for 1967* (6)§§	*Variance between 1966 Adjusted and 1967 Proposed* (7)
Revenue	$10,000	+$100	−$25	0	$10,075	$12,090	+$2,015
Variable costs (by category)	4,000	+ 50	− 50	−400	3,600	4,320	+ 720
Contribution	6,000	+ 50	+ 25	+400	6,475	7,770	+ 1,295

* The improved marketing added $100,000 to revenue; it cost $50,000, and the result was a $50,000 net addition to contribution.

† A cut in inventory sizes stocked reduced revenues by $25,000 but cut cost $50,000, leaving a net contribution of $25,000.

‡ Capital expenditure did not affect revenue, but it did reduce manufacturing expense and direct labor cost by $400,000. (The resulting net contribution of $400,000 would be needed in part to cover the cost of the capital expenditure.)

§ Net result of changes in column (4).

§§ Figures show what would happen if revenues were then increased by 20 per cent with no other changes.

Year	*Amount of Contribution*	*Increase from Previous Year*
1966	$50,000	$50,000
1967	60,000	10,000
1968	70,000	10,000
1969 and later	70,000	

Note the $50,000 increase for the 1966 budget (which is the same figure as that shown at the bottom of Column 2 in Table 1), the $10,000 increase for 1967, the $10,000 increase for 1968, and nothing thereafter.

The same thing would be true in the case of approved capital investments. In this way, an automatic check of the results of investments is obtained. More details are provided in the note to Table 1.

In other respects, the presentation, approval procedure and analysis of actual results against budget would follow the same pattern that is generally used in ROI systems.

Organizational Resources

Implementing a marginal contribution system may require some upgrading of control techniques. The most important needs are:

1. *A good budget analysis group.* Since a division's actual contribution is being compared with its budgeted contribution, it is important (a) that the latter represent satisfactory performance, (b) that the various divisional budgets reflect a comparable degree of difficulty, and (c) that variances be analyzed completely and accurately. As stated earlier, any good management control system requires a good analytical group; however, the need is more evident in the case of a marginal contribution budget system.
2. *A good capital investment analysis system.* Every company needs a good system for evaluating proposed capital investment expenditures. If marginal contribution budgets are used, however, it is even more necessary that capital

investment projects be explicitly evaluated and approved, with the timing of future cash flows made very specific.

3. *A good standard cost system.* Because some intracompany transfers are made at standard marginal cost, it is necessary to have a good standard cost system, and it is useful to have a direct costing system. Obviously, these will be required for good cost control in any event.
4. *A profit analysis group at the corporation level.* Under the marginal contribution system, fixed costs are not charged to products. As a result, where estimates of full cost are needed to guide pricing decisions, diagnose unprofitable conditions, or evaluate the effect of changes in capacity, it is necessary to have a corporate group that can provide this information.

What is Lost?

If a company changes over from ROI to the management control system just described, must it sacrifice important advantages possessed by the ROI approach? To be more specific, it is generally alleged that ROI has two principal advantages over other methods of management control:

1. It provides management with a means of gauging the profitability of the various parts of the company.
2. It serves to make the manager responsible for the level of his investment.

The question is whether these benefits are given up when the transition is made.

Gauging Profitability?

It is comforting to top management to have a figure that means something in an absolute sense. A division's ROI can be evaluated as good, medium, or bad. For example, a loss or a nominal return is bad; a return of from 5 per cent to 10 per cent after taxes is usually considered fair, and a return above 10 per cent is regarded as good. However, when you divide the typical company into profit centers, using questionable transfer prices and different capitalization methods, the results can be meaningless. Often you will see one division (say, a marketing division) earning a very large return, while another division (say, a manufacturing division) earns a low return, or vice versa. When the situation is analyzed, you may find, as suggested earlier, that the high return of the marketing division resulted from low asset values due to a capitalization policy, or that the manufacturing division's low profits resulted from transfer prices which were of questionable validity. This being the case, how serious is the loss from eliminating ROI from the control system?

In a sense, there is only academic value in knowing what the profit is on a certain segment of the business if all segments are essential to the business. Who cares what the profit is on a railroad bridge if you cannot operate the railroad without it? The importance of the bridge lies in its effect on the integrated profit of the system as a whole.

If, on the other hand, management wants division profitability data anyway, it can have a special study made centrally because then organization barriers can be ignored. In other words, the analysis can be made of the integrated profit *by type of business* rather than by organizational units, which often represent artificial breakdowns (e.g., separation of marketing and manufacturing).

Investment Control?

As for the objection that without ROI the manager will not be held responsible for his investment decisions, the answer is that there are better ways to control investment decisions.

The basic control of investment actions comes at the decision point. After the investment is made, the costs are sunk and have no impact on new decisions. It is necessary, however, for management to follow up on capital investment projects and to compare actual performance with that stated on the project proposal. We believe that this can be best accomplished by integrating such comparisons with the marginal contribution budget. The projected contributions from the capital investment proposal are added to the marginal contribution budget for the appropriate years, as indicated previously. This will give much better control than simply adding the investment to the investment base and subtracting the depreciation from profits.

It is common to hear managers say, "We can't really show a profit on a new plant until it is old, because of accelerated depreciation and start-up expense plus incremental marketing cost. Then we make a killing." Often both managers and directors complain that there seems to be no correlation between investment criteria and the resulting accounting profits reported. In fact, the reported profits can be significantly different from the programmed ROI even when the project goes as scheduled. The moral is that capital expenditure decisions must be made on the basis of an independent, thorough analysis of their impact on the corporation's cash flow and profitability. Such an analysis is not part of the control system. The only time the control system should be brought in is when capital expenditure decisions are related to subsequent budgets.

Advantages and Problems

What are the advantages of the proposed system?

First, the settlement of transfer prices is no longer a problem because market prices are used only where a genuine market exists. Furthermore, it will not be to a selling division's advantage to obtain higher prices inside than market prices because:

1. If it does obtain higher prices, it will have a correspondingly higher budgeted contribution.
2. If it has to sell some of its products outside, it will show an unfavorable variance unless the transfer price is realistic or equivalent to the market price, and the full impact of such volume variance will be assigned to it as the division responsible for the sales volume.

A second set of advantages has to do with the marginal contribution budget. Use of this budget means that the manager is evaluated on the actions taken during the period under review. Action taken in previous periods by him or his predecessor will not affect current performance to the same extent as under other approaches. Further, he will be motivated to maximize the contribution earned by his division that is consistent with company interests, and he will not be concerned with changing accounting values to improve performance. What is more, top management will not be misled by absolute rates of return; each division will have an objective consistent with its potential.

A third set of advantages is offered by the fixed- and managed-cost budget. The tendency to take unwarranted action to improve short-term profits will be mitigated. For instance:

Research expenditures are often reduced to meet short-term profit goals when ROI is the basis of performance evaluation. A separate fixed- and managed-cost budget will greatly strengthen the ability of cor-

porate management to balance short-term and long-term considerations. It will eliminate the temptation to meet current profit goals by reducing expenditures that should pay off in the future.

Finally, the capital expenditure budget is a source of benefit. The system of adjusting future contribution budgets by the amount of projected cash flow and contribution gives management a better chance to evaluate (and consequently to control) capital expenditures than can be achieved by conventional profit-center and ROI systems.

Possible Difficulties

Clearly, no management control system will be completely effective in all circumstances, and the proposed system is no exception to this generalization. What are some of the problems that could occur when the new approach is used?

Determination of Marginal Costs. Marginal costs are those that change as a result of a given decision. Consequently, marginal costs will be different under different circumstances. In fact, the marginal costs of producing a given volume of a particular product could be different each time it is produced. Clearly, it is not practicable to calculate standard costs for all possible production conditions. On the other hand, it is undesirable to transfer goods at actual costs because this removes the incentive for the manufacturing division to control costs.

We believe that the definition of variable costs given earlier in the article will be satisfactory for most companies if they are working at or below nominal capacity; a second price is necessary when production exceeds nominal capacity. If, however, there are significant differences in costs at different volumes, management may have to use several prices. Even though this is inconvenient, it is necessary to know these costs under any system if intelligent decisions are to be made.

One of the advantages of the proposed system is that it will become obvious when transfer prices differ significantly from actual costs. The manufacturing divisions will show large variances. Whenever this occurs, management is warned to investigate the causes to be sure that transfer prices are actually approximating marginal costs.

Transfer Price Disputes. The proposed system will eliminate disputes with respect to market prices. It will not, however, completely eliminate transfer price disagreements. Where no market exists, the level of standard costs could be a source of contention. Bear in mind, though, that motivation for disputes is sharply reduced.

Incentives to Improve Costs. An argument against the proposed system can be made on the grounds that those divisions which transfer goods at standard marginal costs will have no incentive to improve performance by developing new processes or acquiring new facilities. A similar argument is that these divisions will no longer have downward cost pressure from other divisions or from the marketplace.

There certainly can be some truth to such arguments. Fortunately, however, it is not difficult to make compensating adjustments which will ease the problems. For example, cost improvements over the year can be made part of top management's evaluation, and part of the division manager's compensation can be based on such improvements. Under any system, if a division manufactures entirely for other divisions of the company, the major responsibility is manufacturing costs, and the ability to perform in this area should be the principal criterion of evaluation. In

fact, where this is true, the proposed system will be superior to ROI because performance will not be obscured by artificial sales prices, arbitrary investment amounts, or uncontrollable shifts in volume or mix.

Cost Interdependencies. Another potential problem with the proposed system is the possibility that a variable cost might be reduced by increasing a fixed cost. We do not see this as being a common problem, but if it should occur, there will be a variance produced in both the managed cost and the variable cost budget.

Divestment of Unused Assets. If the manager is not charged with the value of the assets that he uses, what incentive will he have for getting rid of unused assets? (This situation is the opposite of that in an ROI system where a manager may have an incentive to get rid of assets that *are* economical.) The penalty here is indirect. Assets represent capacity. Production and, thus, revenue expectations are geared to capacities. The skill of the budget-setting establishment will determine whether this is a problem.

All considered, the difficulties are real, but they do not appear to be significant enough to be a deterrent to a system based on the proposed principles. We would like to point out, however, that none of the problems mentioned creates a conflict of interests between divisional and company goals. For instance, performance is not *hurt* by failure to get rid of unused assets. The trouble is simply that there is no positive incentive. Consequently, it is relatively easy to correct these situations where they occur. In contrast, almost all ROI systems create conditions where it is to the *dis*advantage of the divisional manager to take optimum action from the corporate viewpoint, and these conditions *can* be very difficult to correct.

Conclusion

In any very large company, there are many decisions which cannot be made by top management. Some form of management information and control system is a necessity in order to prevent size and complexity from becoming major handicaps. Such a control system must perform two functions:

1. Motivate division managers to make the same decisions top management would make, if it could.
2. Provide top management with some evaluation of how these decisions are affecting the operation.

Many efforts have been made to break large companies into independent administrative units which can be evaluated as if they were independent companies. Such efforts have, at times, worked reasonably well if the operations were in fact truly independent and a long enough time period was used for evaluation. But the approach does not prove very satisfactory for control. Over short periods of time the conventional financial accounting system provides too many subjective inputs which distort evaluation and eviscerate information used for control purposes. When used for purposes of comparing one division's performance with another's, the information is even less revealing. Profit on sales means little, since the basic character of the business of various divisions may be quite different. This leaves ROI the only common measure, and while it is useful for long periods, for short periods it is subject to quite arbitrary allocations of income and expense.

Even for independent companies, ROI is viable as a measure of performance only when substantial periods of time are considered. For divisions of a large company, over a short time, it

can be so misleading that it is destructive. One of America's largest companies had what was nicknamed the "Two and Twenty Club." This referred to the fact that a new division manager had to achieve a 20 per cent return on assets or be replaced in two years. It was said in this company that a really sick operation always chewed up three consecutive managers before the cumulative results of their efforts would permit a successor to meet "Two and Twenty Club" entrance standards.

In many large companies, the administrative units designated as profit centers simply are not independent. A major portion of their volume may be coupled together; a major portion of their costs may be either allocated or shared; the profit or ROI of one may be a direct deduction from the apparent profit of another, and so on. Any error in setting transfer price becomes a windfall for one unit and a punitive assessment against another.

Meeting Objectives

From our perspective, it appears that the real objective of a management control system is to provide knowledge of what is happening when a division or operating unit is not in fact meeting expectations.

In a profit center, failure to meet profit, budget, or ROI standards can result from difficulties in a variety of areas—sales volume, product mix, pricing, costs, or assets used. A detailed analysis is necessary to determine which factor has affected budget performance. For the division in an integrated company, it may prove that most of the reasons for a failure have been determined by decisions in other divisions.

Ideally, a good management control system:

1. Should hold the management of a division responsible only for what it can control
2. Should immediately signal variations in actual performance from expected performance

A control system based on contribution and managed-cost budgets can do this. ROI may still be useful where the central group acts essentially as a holding company, e.g., a venture capital company that is principally concerned with long-run evaluation. Most management control systems, however, are designed for short-run control. Here, ROI definitely falls down. Any company with significant intracompany transfers, with frequent changes of managers, or seeking month-to-month control of profit centers should find the new system a far better answer to its needs.

ACCOUNTING IMPLICATIONS OF A MATHEMATICAL PROGRAMMING APPROACH TO THE TRANSFER PRICE PROBLEM

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The transfer price problem is examined as a problem of decision-making and performance evaluation where market prices are available, as well as where they are not available. An application of mathematical programming to the transfer price problem is illustrated, and implications of its use are explored. The difficulty of designing a system that permits an optimal allocation of a firm's resources and, at the same time, serves to control and evaluate managerial functions is emphasized.

This paper examines several cross-disciplinary efforts to solve problems of intrafirm resource allocation in an attempt to determine their possible significance to managerial accounting. For this inquiry, a system of transfer prices is defined as a set of internally derived prices for guiding the intra-company transfer of productive resources. We assume that this system is restricted to optimal allocation of a fixed set of productive goods and services; that is, the supply of these goods is given, and the transfer price problem is the short-run efficiency problem—how can a firm "best" utilize a fixed quantity of tangible and intangible resources.

Decentralization, Information-Processing and Transfer Prices

The need for a transfer pricing system develops from a delegation of that authority for which central management is ultimately responsible. This "decentralization" ranges in degree from the control of a single variable to that of complete freedom in determining levels, types, combinations, customers, and sources of inputs or outputs for an entire division.

Presumably, decentralization is chosen in the expectation that the resulting organizational structure will better serve the firm's objectives or goals. Two general arguments which favor decentralization are: (1) the employees will be better motivated and this increased motivation will lead to an increase in productivity, and (2) decentralized managers are in better position to process information concerning resource allocation.[1] Although these are interrelated, our interest is in the assumed economies of information processing.

Part of the accounting function is to determine the type of information to be collected and the method of its classification for the purposes of both decision-making and evaluation throughout

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[1] For a detailed account of the behavioral aspects, see George Benston, "The Role of the Firm's Accounting System for Motivation," *Accounting Review,* XXXVIII (April, 1963), 347–54. The economics of information processing are implicit in competitive economic models. For example, see F. Hayek, *Individualism and Economic Order* (Chicago: University of Chicago Press, 1948), especially Chap. 4.

all management levels. Traditionally, accounting employs a single information system to aid both in decision-making and in interpreting the results of the decision-making process. For example, the use of standard costs is predicated upon an information system resulting from managerial goals (decisions made) and the measurement of events in reference to these goals (evaluation control).

Consequently, the accountant will wish to judge the impact of various proposals for transfer pricing on the system's ability to perform simultaneously both objectives—the providing of information leading to the optimal allocation of a specific quantity of resources and the generation of the complementary information which can be used to control and evaluate the allocation decision.[2]

A related interest in this allocation problem may be derived as a corollary to this basic methodology. If the accounting method is successfully implemented, only those individuals actually making the allocation decisions can be evaluated by the system. Thus, we must examine proposed pricing systems in terms of the system's ability to guide that group in management most likely to make the allocation decisions.

In the pages following, the notion of information processing is developed as a basis for examining the potential applications of recent developments in programming to the accounting problem of transfer pricing. We first consider the situations where "real" prices are available for both decision-making and evaluation. This facilitates analysis of those situations requiring artificial prices. It is in the derivation of artificial prices that the benefits from programming methods are to be reaped.

[2] See Joel Dean, "Decentralization and Intracompany Pricing," *Harvard Business Review,* XXXIII (July–August, 1955), 67.

"Real" Prices and Intrafirm Resource Allocation

If resources are bought and sold in a competitive market, real prices exist for use in the firm's internal transactions. Such prices assume that the outputs of supplying divisions can be sold at the given market price which permits the assumption of constant acquisition price to the purchasing divisions. Given these conditions, the resulting market prices satisfy the decision-making needs of divisional managers; also, they enable top management to evaluate the general degree of effectiveness of divisional managers.

Fundamentally, "real" prices are effective under these overall conditions because they reflect the opportunity costs of the intrafirm transactions.[3] That is, if the manager of one division is willing to supply a unit of output to another division, his price should reflect, as a minimum, the amount he could have received from his next best alternative. The opportunity cost is constant over all ranges of output. Similarly, the purchasing manager should not be made to pay a price greater than that of his next best alternative which is also constant over his range of demand. These conditions prevent or discourage

[3] A qualification is necessary to the extent the price obtained by the supplying division in the open market is less than the price which must be paid on the open market by the purchasing division. This situation exists because of the economics of integration. The equilibrium conditions for such situation have been worked out by J. R. Gould, London School of Economics, in "Internal Pricing in Firms When There Are Costs of Using an Outside Market," *The Journal of Business,* XXXVII (January, 1964), 61–67. Its main point of relevance to this paper is its concern over the weakness in the procedures of obtaining equilibrium which generally involve divisional negotiation. We believe, however, that the conditions for evaluation reduce the dangers which could develop.

attempts to misquote or rig the prices to be employed. Also, these are the ideal conditions for the use of an income figure as a control and evaluative device for central management in their comparisons of performances which indicate the relative degree to which opportunities are seized by divisional managers.

If the divisions do not operate under these conditions of competition, central management must recognize that the resulting market prices may not represent the opportunity costs of divisional transactions. Under these conditions the demand curves of the selling divisions will be downward sloping for increasing levels of sales to outside firms and/or the supply curves will be upward (or downward) sloping for greater levels of purchases made from outside firms. In order to achieve an optimal allocation of the firm's resources, it is necessary to work with the revenue and cost functions of both the supplying and the purchasing divisions, since the relative slopes of the functions will vary between divisions.[4] Thus, it is necessary to relieve one of the divisions of profit responsibility. However, it might be more practical to accept market price as an approximation of the opportunity costs of intrafirm transactions, since the data needed to centralize the decision-making process may be available only after considerable delay.

A compromise solution seems reasonable especially if cross-elasticity of demand exists between the outputs of related divisions. Under such circumstances an optimal solution to the firm's allocation problem would require a system of "taxes" and "bounties" to supplement market prices (depending on whether the sales of one division had a favorable or unfavorable effect on another division's sales).[5] Such a system might require more administrative effort than appears reasonable. Moreover, the ability to design the system of taxes and bounties presupposes (perfect) knowledge of the cost and revenue functions in which case decentralization would serve no useful purpose.

We may conclude that in general the existence of market prices for divisional outputs will provide a basis for transfer prices which either allows complete decentralization—perfect competition—or which allows degrees of decentralization based upon the considerations above. An outside set of prices not only provides a reasonable measure of the opportunity costs of diverting units to related divisions, but it suggests that other firms are operating under conditions similar to the decentralized divisions. References are thereby established for the evaluation of the decentralized managers.

In the event still more complete programs of decentralization are desired under conditions of imperfect competition, these may be achieved through processes of negotiation where the transfer prices are determined in reference to cost and revenue functions of respective divisions. In evaluating the resulting performances of the divisional managers, however, the central management may be evaluating their ability to negotiate rather than their ability to control economic variables. Accordingly, the information economies of decentralization may be more apparent than real.

Intrafirm Transfers—"Real" Prices Not Available

The more complex problems of intrafirm pricing develop, however, when

[4] Jack Hirshleifer, "On the Economics of Transfer Pricing," *The Journal of Business,* XXIX (July, 1956), 172–84.

[5] Jack Hirshleifer, "Economics of the Divisionalized Firm," *The Journal of Business,* XXX (April, 1957), 96–108.

the firm produces its own specialized resources but desires a program of decentralization.[6] The assumption of specialized resources implies that either no market exists for these resources (other than internally) or that market prices for related items are irrelevant for the short run. In other words, the market place offers no alternative to either the purchasing or the supplying divisions so that other methods must be developed to determine the opportunity costs of divisional transactions. One general approach in determining transfer prices for these situations involves the use of various measures of standard or actual costs. These include full cost, full cost plus, and marginal or variable costs.[7]

If no market exists for the specialized resource, the opportunity costs of supplying units of output are limited to the marginal costs of producing additional units.[8] A purchasing division would continue to make additional purchases until the cost of obtaining the inputs (the transfer price) is equal to the additional revenue obtained from selling the final output. A measure of decentralization is possible since the manager of the purchasing department has control over the level of inputs he will purchase.

Since the manager of the supplying division is not given the authority to determine his level of output, his performance cannot be evaluated by a traditional measure of profit or loss. Any attempts to develop reports of profitability must lack the substance to motivate the manager of the supplying divisions, given the conditions just considered. It is more rational, therefore, and, at least as useful, to apply more traditional measures of cost control to evaluate the results of the manager of the supplying division.

It is evident that transfer prices based upon full cost or full cost plus do not provide a basis for determining the optimal output levels of the divisions; these prices do not reflect the opportunity costs of the divisional transactions. Further, it is doubtful that these prices will motivate divisional managers in an appropriate manner. While it is obvious that all divisions affect the final profit of the firm, it does not seem useful to develop some form of profit and loss statement based upon full cost or full cost adjusted by markups. Because the amount of profit is so far-removed from the control of the managers of supplying divisions, it is not likely that these measures will lead to the appropriate actions on their parts. Indeed, systems of standard costs and flexible budgets are intended to overcome this deficiency which extends the evaluation of performance beyond the effective span of control.

From this, it is concluded that marginal costs of production or distribution can be used as a basis for transfer prices when market prices are not relevant to the output of the supplying divisions. Marginal costs can reflect the opportunity costs of divisional transactions.

Market Prices Not Available—Alternative Uses of Fixed Facilities

These marginal costs remain sufficient, however, only in the event the demand for the outputs of the supplying divisions is limited to one purchas-

[6] In fact, Dearden uses the extent of availability of market prices as a basis for classifying approaches to the transfer price problem. See John Dearden, "Interdivisional Pricing," *Harvard Business Review,* XXXVIII (January–February, 1960), 117–25.

[7] Howard Greer, "Divisional Profit Calculation—Notes on the 'Transfer Price' Problem," *N.A.A. Bulletin,* XLIII (July, 1962), 6.

[8] It will be recalled that we are limiting our discussion to time horizons which are not sufficient to permit investment decisions.

ing division. Assuming several divisions desire the output of the supplying division, and the facilities are limited, the opportunity cost of supplying any one division as opposed to another is the greater of the marginal costs of producing the output or the revenue lost by diverting the resource from alternative uses.

Conceivably, the manager of the supplying division could allocate his scarce facility to the most profitable output, e.g., on the basis of the highest net contribution per unit of scarce facility. In this event the managers of the purchasing divisions will no longer control their input levels. In this respect, the manager of the supplying division tends to occupy a position similar to one central management might occupy with as much efficiency. It is doubtful that an elaborate program of decentralization would be developed in these situations.

A more serious limitation to this procedure arises when the operations of the organization involve the use of substantial fixed facilities common to a large range of possible outputs. The conditions of interdependence then require a formal programming solution, since no single supplying manager is in a position to determine an optimal allocation without affecting the activity levels of other supplying divisions of the organization. That is, a formal solution must be obtained by a more centralized management using the techniques of linear and nonlinear programming. We wish now to consider whether these formal solutions are consistent with programs of decentralization.

The Application of Programming to Transfer Pricing: Linear Restraints and Linear Objective Functions

It is generally accepted that, to the extent the problem can be formulated properly, linear programming offers a technique for allocating scarce resources among different choices of output. The problem here is to determine whether the allocation ought to be carried out by divisional managers, and assuming this procedure is considered feasible, what amount of information will be required by the divisional managers in order to accomplish these allocations.

The application of linear programming to the transfer pricing problem is based upon the relationship between the primal and dual solutions in the linear programming problem. That is, "To every linear programming problem there is an associated, sometimes somewhat artificial, minimization problem and vice versa."[9] The symmetry of these problems is such that, ignoring theoretical complications, the optimal solution of the primal is equal to the optimal solution of the dual. In simple notation, $\max z = \min Z$ (see the Appendix at the end of this reading).

The optimal values of the dual variables have often been called "shadow prices," since they are considered to reflect the imputed values of the scarce resources implied in the primal problem. These prices are believed to offer the basis for a system of transfer prices. Specifically:

> Decentralized administration...has many advantages, but it is important to note that its success depends upon the establishment of proper accounting prices...we have now seen that linear programming can be used for this purpose and is thus a significant aid as well as an alterantive to cost-accounting guidance.[10]

[9] William J. Baumol, *Economic Theory and Operations Analysis* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1961), p. 91. The notations used here and in the Appendix correspond to those used by G. Hadley, *Linear Programming* (Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1962), Chap. 8. We are ignoring theoretical complications in these statements.

[10] R. Dorfman, P. A. Samuelson, and R. M. Solow, *Linear Programming and Economic Analysis* (New York: McGraw-Hill Book Company, 1958), p. 184. See also G. Hadley, *op. cit.*, p. 485; and W. Baumol, *op. cit.*, p. 327.

It is necessary to consider this proposal in more detail.

If we suppose that top management has solved the optimization problem, it possesses the information needed to determine both the types and the amounts of the outputs which should be produced. Presumably, top management could send the complete solution to the divisional managers or, rather, direct them to produce given levels of various products. With this knowledge we must wonder why a program of decentralization is desired.

Before considering this question, however, we should point out that the existence of "shadow prices" is not a sufficient condition to lead to an implementation of the optimal solution by divisional managers.[11] That is, shadow prices will only permit these managers to select the types of outputs which should be produced, but the exact levels of outputs must be determined by alternative means. Conceptually, the calculation of these output levels would presuppose the ability to solve large systems of simultaneous equations. While this may be possible, it does not seem a feasible manner of implementation. We might bypass this problem by assuming some practical method has been determined which will reduce the likelihood that divisional managers will authorize production of nonoptimal levels of output.[12] Our main concern is the degree to which programming permits decentralized operations. We can approach this problem by considering the alternative forms of information economies which may exist.

Evaluation of Divisional Managers

It seems evident that the allocation problem is best solved by centralized management when conditions permit a practical linear programming solution. However, the calculation of a linear programming solution is only part of the overall allocation problem.

For example, organizations may be designed in such a manner that divisional managers would still be in the best position to collect current information concerning input prices, output demands, and so on. Thus, while central management coordinates the activities of the firm, the input data used to solve the allocation problem are supplied by divisional managers. This would permit these managers to choose the most economic combinations of input factors for the types of possible outputs, the sources of supply, the outlets for the outputs, etc. Thus, a considerable and significantly important degree of decentralization would be possible under these circumstances. The imputed prices sent by central management would simply be a means of implementing the solution to the firm's allocation problem, but the accuracy of the data used to derive the solution would actually be a responsibility of the decentralized divisions.

The evaluation of the performances of these decentralized managers, given these conditions, however, would be a somewhat more difficult problem. The central management could use the programming solution as a means of estimating the profit of the firm. Later the actual performances of the divisions could be compared to the anticipated profits to determine how well they anticipated technical coefficients and input and output prices, including the degree to which they followed or were able to follow the optimal solution. If the profit performances of the firm could be compared to the performances of other firms, central management would also have a method of indirectly evaluating the ability of the divisional managers to determine the most economical means for producing the possible outputs.

An alternative approach might in-

[11] See G. Hadley, *op. cit.*, Chap. 11.
[12] *Ibid.*

volve the establishment by central management of the input standards for the various outputs within a formal system of standard costs. Although this reduces the attainable degrees of decentralization, a knowledge of the imputed values of the resources would still prove useful. For example, the lower level managers could be encouraged to review input and output variables continually in order to determine if the original solution remains optimal. More specifically, solutions to linear programming problems permit a storing of information needed to determine the degree to which changes in certain of the variables are critical to the original solution. The ranges of those changes in the values of the optimal set of variables which would alter the solution could be transmitted by central management for comparison by divisional managers to actual events. Essentially, a program of decentralization would be developed on the basis of the techniques of parametric programming, since the positive activities will form the matrix of the coefficients of the optimal solution.

In conclusion, these and other possibilities of information economies may exist which offset the apparent need for highly centralized operations when using linear programming to solve the allocation problem. Indeed, some of the techniques of nonlinear programming, which we shall mention shortly, implicitly assume that such information economies are real. In all instances, however, the evaluation of performances must be developed in terms of the limits of decentralization which exist. In the applications of programming we have seen that these limits are somewhat peculiar, and the evaluative framework may develop to be similarly so.[13]

[13] Some of the characteristics of the situations of equilibrium and information processing just described are not completely unlike the conditions for equilibrium in a socialist economy. For example, see O. Lange, F. M. Taylor, and B. E. Lippincott, eds., *On the Economic Theory of Socialism* (Minneapolis: The University of Minnesota Press, 1938, 1948), pp. 72–82.

Nonlinear Programming

In recent years developments in nonlinear programming have taken place which may offer advantages to the transfer price problem when the problem situations involve nonlinear functions.[14] Unfortunately, nonlinear solution techniques are rather complex so a discussion of the implication of these techniques must be in general terms only.

One of these developments, the decomposition principle,[15] offers a possible basis for negotiation between top management and the divisional managers. The techniques for the decomposition principle, while resembling the techniques of linear programming, are beyond description here, but very briefly the approach takes advantage of the fact that not all the constraints in the linear programming problem are common to all the activities.

More specifically, the original matrix is structured so that sets of equations form smaller linear programming problems which are linked together by a common set of constraints. The system may be solved in the usual manner, but it may be more feasible to solve the individual problems and then attempt to find a convex combination of the individual solutions which will satisfy optimally the common constraints as well. In the process of determining the optimal solution to the over-

[14] Philip Wolfe, *Recent Developments in Non-Linear Programming,* The Rand Corporation—R-401-Pr., May, 1962.

[15] For example, see G. B. Dantzig, and P. Wolfe, "Decomposition Principle for Linear Programs," *Operations Research,* VIII (January–February, 1960), 101–11; a related article appears in *Econometrica,* XXIX (October, 1961), 767–78.

all problem, new "prices" are generated which are then used in re-solving the smaller problems. It can be envisioned that individual managers, who would be in charge of the activities represented in the smaller problems and who could not optimize their activities independently of each other, would send their individual programming solutions to a central management where the new prices would be generated and then sent back to the divisional managers. The process is repeated until the optimal solution is obtained. The relevant point is that, if this method can be applied in practice, it will provide a basis for negotiation between the departmental and central management levels. In this respect, it would not be necessary for the divisional managers to negotiate with each other. This in itself may be an advantage, since situations of negotiation between divisional managers may degenerate into personal conflicts.[16]

The overall process may be difficult to apply in practice, however, because of the possible extent of negotiations which might be necessary before the convergence to an optimum takes place. If the needed negotiations are extensive, the departmental managers will spend considerable time calculating solutions. On the other hand, the organizational structure may be so complex that the individual divisional managers can better process information concerning their activities than can a central management which must coordinate the activities of several divisions. Additionally, this type of structure may even permit central management more opportunity to compare the performance of divisional managers to each other or to other "outside" firms. In any respect, the system of prices which is developed using these techniques should be less arbitrary than the prices which are developed utilizing the accounting methods of costs or by referring to nonrelevant market prices.

Methods of determining prices have been suggested for use where nonlinear functions of several variables are to be maximizing subject to constraints.[17] In the process of maximizing these functions under constraints, the marginal value of the resources constraining the problem may also be computed. These prices would be applicable, for example, where the managers of two or more divisions demand the services of a single resource (the constraint). In that case the activities of each manager are no longer independent.

The practical use of nonlinear programming as a basis for transfer prices is not immediately at hand, since efficient methods for solving large systems of nonlinear programming problems are still being developed.[18] Consequently, an evaluation of the uses of these methods for accounting purposes would be premature, although some of the remarks made earlier regarding the possibilities of information economies will apply under these programming conditions also.

Other Implications

The shadow prices relative to scarce resources provide the accountant with a method for developing an analysis

[16] Joel Dean, *op. cit.*, p. 67.

[17] A simple illustration is contained in Baumol, *op. cit.*, pp. 56–58; for additional applications see also Paul H. Daus and W. M. Whyburn, *Introduction to Mathematical Analysis* (Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1962), pp. 166–68; and H. W. Kuhn, and A. W. Tucker, "Non-Linear Programming," in *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability* ed. J. Neyman (Berkeley: University of California Press, 1951), pp. 481–92.

[18] A late summary of these techniques by W. S. Dorn is contained in "Non-Linear Programming—A Survey," *Management Science,* IX (January, 1963), 171–208.

of whether to increase or abandon the organization's specialized resources.[19] These prices indicate the "worth" of these resources to the final profit of the firm. The complexities of multiproduct firms may be such that an informal method of analysis is no longer feasible. The use of these prices in evaluating the possibilities of increasing or decreasing facilities is not as straightforward as it might seem unless it is assumed that all resources are increased or decreased as a complete unit. The methods of parametric programming are really needed to determine the effect of changing the available capacity of a single facility.

This suggests an implication of programming for systems of standard costs. Most systems of standard costs are based on engineering estimates of transferring the incomplete units from division to division. If the only choice which exists at all stages of completion is either to complete or not to complete the unit, then the standard variable costs may be considered as appropriate measures of the opportunity costs of producing the unit up to various stages of completion. If the facilities are being strained, the standards must be adjusted to include the opportunity costs of using the facility to produce the product or unit. This situation may occur when the firm's fixed facilities are capable of producing more than one type of output. Thus, programming may have relevance to standard cost systems to the extent that the imputed values of the scarce facilities may be incorporated within the system as a means of measuring the opportunity costs of processing the units of output.[20] In this manner the engineering standards may be adjusted to reflect the economic conditions. The standards, therefore, will be useful for decision-making and control purposes. The more common standard cost systems seem to be designed to accomplish the single purpose of controlling divisional transactions to insure that they remain consistent with some centralized plan. If no alternative exists but to carry out the plan, the standards are sufficient. If other alternatives exist, these must be reflected within the system of standard costs. Programming may offer a means of accomplishing this need.

Conclusion

No attempt has been made in this paper to develop the mathematical techniques which are necessary to implement a system of transfer prices, although an appendix had been included to illustrate more fully some of the remarks. Rather, our purpose was to consolidate the material on transfer prices in order to evaluate the basis for applying programming. Further interest in the mathematical techniques can best be served by referring to the sources suggested.

One thing has become apparent in this discussion. The faith in a simple measure of performance, such as a profit and loss index, is not completely warranted in the area of transfer pricing. If real prices exist for units of outputs at the stages where decision-making concerning resource allocation is appropriate, then these prices will serve both the function of decision-making and the function of evaluation. A profit and loss index is as appropriate

[19] Dorfman, Samuelson, and Solow, *op. cit.*, p. 184.

[20] This view is not inconsistent with the recommendations made by Moonitz and Sprouse concerning the valuation of inventories. See R. T. Sprouse and Maurice Moonitz, *A Tentative Set of Broad Accounting Principles for Business Enterprises*, Accounting Research Study, No. 3 (New York: American Institute of Certified Public Accountants, 1962).

here as it is for external reporting on a firm's economic results.

If it is necessary to develop fictitious prices, however, the concurrent accomplishment of these two objectives seems difficult. While it may be possible to develop a system of prices which will guide the divisional managers in a manner consistent with an overall plan of resource allocations, the same system of prices cannot be relied on to motivate divisional managers toward some higher level of profits since they will have only a token amount of control over these profits. On the other hand, we may develop a system of prices which will permit the calculation of divisional profits or losses, but the system may not permit the determination of the optimal allocation of the firm's resources.[21]

As a general conclusion we suggest that the relationships between the decision-making and the control and evaluation phases of managerial functions be kept in the forefront in considering the design of accounting systems for programs of decentralization regardless of the degree to which decentralization will be carried out. In this respect the increasing applications of programming to solve the allocation problems of complex firms can no longer be ignored by accountants.

Appendix

Consider the following linear programming problem:

$$\begin{aligned} 8x_1 + 3x_2 + 4x_3 + x_4 &\leqq 7 \\ 2x_1 + 6x_2 + x_3 + 5x_4 &\leqq 3 \\ x_1 + 4x_2 + 5x_3 + 2x_4 &\leqq 8 \\ \text{Max } z = 3x_1 + 4x_2 + 1x_3 + 7x_4 & \end{aligned}$$

The problem may also be represented with the use of the vectors a_1, a_2, a_3, and a_4 as:

$x_1a_1 + x_2a_2 + x_3a_3 + x_4a_4 \leqq b$ where a_1 is the vector $\begin{bmatrix} 8 \\ 2 \\ 1 \end{bmatrix}$,

a_2 is the vector $\begin{bmatrix} 3 \\ 6 \\ 4 \end{bmatrix}$, etc.

The dual to this problem may be formulated as:

$$\begin{aligned} 8w_1 + 2w_2 + w_3 &\geqq 3 \\ 3w_1 + 6w_2 + 4w_3 &\geqq 4 \\ 4w_1 + w_2 + 5w_3 &\geqq 1 \\ w_1 + 5w_2 + 2w_3 &\geqq 7 \\ \text{Min } Z = 7w_1 + 3w_2 + 8w_3 & \end{aligned}$$

If A is the matrix of the vectors a_1, a_2, a_3, a_4 and c is the vector of prices of the x_5, the symmetry of the maximization and the minimization problem may be indicated in the following manner:

Primal	*Dual*
$Ax \leqq b$	$A'w \geqq c'$
Max $z = cx$	Min $Z = b'w$

where the primes in the dual indicate the transpose of the matrix A and the vectors c and b. This symmetry is further indicated by the fact that if an optimal basic feasible solution is obtained for the primal, and is represented as max $z = c_Bx_B$; the scalar product z will equal the minimum value Z of the dual. That is:

$$\text{Min } Z = b'w = \text{Max } z = c_Bx_B,$$
$$\text{so } b'w\ (= w'b) = c_Bx_B$$

Fortunately, the general procedures of the simplex method can be used to derive sufficient information to compute the value of the optimal solution to

[21] We do not deny the need to establish a conceptual system of measurement, given the objectives of the accounting system. For an attempt in this direction, see G. Shillinglaw, "Toward a Theory of Divisional Income Measurement," *Accounting Review*, XXXVII (April, 1962), 208–16.

the dual problem, assuming the primal is being solved directly. To illustrate how the value of the dual variables may be determined and *also* how this knowledge may be utilized for transfer prices, the initial and final tableaux of the maximization problem are given below. The variables x_5, x_6, x_7 and are the variables necessary to convert the inequalities of the problem into equalities.

Initial Tableau

C_B	*Vectors in basis*	b	a_1	a_2	a_3	a_4	a_5	a_6	a_7
0	a_5	7	8	3	4	1	1	0	0
0	a_6	3	2	6	1	5	0	1	0
0	a_7	8	1	4	5	2	0	0	1
	$z,\ z_j - c_j$	0	−3	−4	−1	−7	0	0	0

$$x_1 = x_2 = x_3 = x_4 = 0$$
$$x_5 = 7; \quad x_6 = 3; \quad x_7 = 8$$

Final Tableau

C_B	*Vectors in basis*	b	a_1	a_2	a_3	a_4	a_5	a_6	a_7
3	a_1	32/38	1	9/38	19/38	0	5/38	−1/38	0
7	a_4	10/38	0	42/38	0	1	−2/38	8/38	0
0	a_7	252/38	0	59/38	171/38	0	−1/38	−15/38	1
	$z,\ z_j - c_j$	166/38	0	169/38	19/38	0	1/38	53/38	0

$x_1 = 32/38$; $x_4 = 10/38$; $x_7 = 252/38$;

$$x_2 = x_3 = x_5 = x_6 = 0$$

Recalling that max $z = c_B x_B$, we have $c_1x_1 + c_4x_4 + c_7x_7 = z$, or

$$[3\ 7\ 0]\begin{bmatrix} 32/38 \\ 10/38 \\ 252/38 \end{bmatrix} = 166/38$$

since min Z = max z or $c_B x_B = w'b$, then $w'b = 166/38$

It will be noted that the vectors a_5, a_6, and a_7 represent the vectors of the coefficients of the slack variables which correspond to the resources b_1, b_2, b_3. Since the $z_j - c_j$ row indicates the net marginal change in z caused by increasing the values of the variables $x_1, x_2, \cdots, x_7$ by an additional unit, the values 1/38, 53/38, and 0 under the columns a_5, a_6, and a_7 represent the change in profit of having either an additional unit of b_1, b_2, b_3 available or having a unit stand idle. We can assume then that these values are the imputed values of the resources b_1, b_2 and b_3 respectively, and in terms of the previous equations, $c_B x_B = b'w\ (= w'b) =$ max z = min Z, we have

$$[3\ 7\ 0]\begin{bmatrix} 32/38 \\ 10/38 \\ 252/38 \end{bmatrix} = [7\ 3\ 8]\begin{bmatrix} 1/38 \\ 53/38 \\ 0 \end{bmatrix} = 166/38$$

The same information is obtainable through another and more general method. That is, if we assume that a_1, a_4 and a_7 are the vectors in the basic solution, and that they are represented as the matrix B, we have $Bx = b$. Pre-multiplying both sides by the inverse of B, $B^{-1}Bx = B^{-1}b = Ix = B^{-1}b$, or $x = B^{-1}b$. Using the previous notation,

$x_B = B^{-1}\,b$. Thus $z = c_B x_B = C_B(B^{-1}\,b)$. Similary, since $b'w = w'b = c_B x_B$, $w'b = (c_B B^{-1})\,b$. The values of the dual variables w_j can therefore be determined by pre-multiplying the inverse of the matrix of the vectors in the basis by the prices of the variables in the solution. For example, if B is the matrix

$$\begin{bmatrix} a_1 & a_4 & a_7 \\ 8 & 1 & 0 \\ 2 & 5 & 0 \\ 1 & 2 & 1 \end{bmatrix}; \quad B^{-1} = \begin{bmatrix} 5/38 & -1/38 & 0 \\ -2/38 & -8/38 & 0 \\ -1/38 & -15/38 & 1 \end{bmatrix}$$

$$w' = c_B B^{-1}$$

$$= [3\ \ 7\ \ 0] \begin{bmatrix} 5/38 & -1/38 & 0 \\ -2/38 & -8/38 & 0 \\ -1/38 & -15/38 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1/38 \\ 53/38 \\ 0 \end{bmatrix}$$

It should be noted that the inverse B^{-1} is also contained in the columns a_5, a_6, a_7 of the final tableau and they are also the columns which contained the original identity matrix in the initial tableau.

Similarly, the vectors of coefficients for any solution, call them y_j, can be obtained by the equation $B^{-1}\,a_j$. For example, a_2 in the final solution which is represented as y_2 can also be determined by the equation:

$$y_2 = \begin{bmatrix} 5/38 & -1/38 & 0 \\ -2/38 & -8/38 & 0 \\ -1/38 & -15/38 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 6 \\ 4 \end{bmatrix} = \begin{bmatrix} 19/38 \\ 42/38 \\ 59/38 \end{bmatrix}$$

Suppose then the manager is given the shadow prices of the resources, 1/38, 53/38, 0. He determines that to produce x_1 he needs to "purchase" eight units of b_1, two units of b_2, and one unit of b_3. His cost will be $8(1/38) + 2(53/38) + 1(0) = 114/38 = \$3$. For each unit of x_1 he produces he receives \$3, so that he breaks even on producing x_1. Similarly, he determines that he will lose 169/38 on each unit of producing x_2 and 19/38 on each unit of x_3; but he will break even on each product of x_4. It will be noted that these values correspond to those in the $z_j - c_j$ row under the columns a_1, a_2, a_3, and a_4. This is not entirely coincidental, for $z_j = c_B y_j = c_B(B^{-1}a_j) = w'a_j$. Applying the process further to a_5, a_6, a_7, it can be determined that only the expressions $c_1 - w'a_1$, $c_4 - w'a_4$, and $c_7 - w'a_7 = 0$. From this the manager can conclude, unless there are alternative optima or unless the solution is degenerate, that these vectors form the matrix of basis vectors, the matrix B. If he can determine B^{-1}, he will be able to determine the levels of x_1 and x_4 and x_7 (slack), since $x_B = B^{-1}\,b$.

Editorial Comment for Chapter 8

The Solomon reading is included in this chapter on decentralized control systems because the relationship between book yield and true yield has such important implications for the design of divisional planning and control systems. We shall discuss a number of these implications here.[1]

During the past ten to fifteen years decentralized profit responsibility has gained widespread acceptance in American industry. More recently a large number of companies have decided that divisional performance measurements would be more useful if they were related in some way to a division's investment base. The significant and surprising extent to which this investment-center concept is replacing the profit-center notion is indicated by the results of a survey conducted by Mauriel and Anthony.[2] Based on responses from 2,643 of the largest companies in the United States—75 per cent of the 3,525 companies contacted—the survey reports that almost 60 per cent employ a return-on-investment (ROI) criterion for evaluating divisional performance.

The Mauriel-Anthony survey disclosures concerning methods of calculating ROI are both interesting and disquieting. The essential conclusion reached is that:

> ...generally accepted accounting principles, including any internal company rules and procedures intended to govern the reporting to outsiders of financial data on the firm as a whole, tend to influence very strongly the methods used in calculating an investment center's profit and investment base. Thus, most companies use net book value in determining the amount of an asset included in the investment base, and almost all companies (97 per cent of the respondents) report using the same method for figuring depreciation for purposes of investment-center profit calculations as that used for their external accounting reports.[3]

Many of the same companies that use such book ROI performance measurement systems employ discounted cash flow (DCF) models as a basis for capital budgeting decisions. Using a planning model (DCF) that takes into account the time value of money and then evaluating subsequent results with a model (book

[1] The discussion to follow is based upon a previously published paper, Alfred Rappaport, "A Capital Budgeting Approach to Divisional Planning and Control," *Financial Executive,* XXXVI (October, 1968), 47–63.

[2] John J. Mauriel, and Robert N. Anthony, "Misevaluation of Investment Center Performance," *Harvard Business Review,* XLIV (March–April 1966), 98–105.

[3] *Ibid.,* pp. 99 and 103.

ROI) that accords no such recognition inevitably leads to serious contradictions. If one accepts the basic premise that DCF planning models which incorporate a time preference for money are an appropriate expression of management criteria, then what are the potential consequences of using models without a time-preference function to evaluate divisional performance? Undoubtedly, they are far-reaching and significant. Consider, for example, the following:

1. Many companies use division ROI rates as a basis for executive promotion and compensation plans.
2. Top management decisions concerning appropriation of funds for expansion purposes can be influenced by comparisons of book ROI ratios among the divisions of the company. The credibility of this supposition is enhanced by the fact that 38 per cent of the Mauriel-Anthony respondents report using a single ROI target rate for all investment centers.
3. Book ROI, when used as a performance evaluation measurement, may actually force a division manager to employ strategies contrary to the long-run interest of the company. Since book ROI is measured in terms of accounting periods rather than long-range periods, the division manager is naturally motivated to seek optimal divisional results for the period he expects to retain his current position. Under these conditions, he may well forego highly profitable projects that will show only modest returns during his expected tenure in favor of less profitable projects with earlier returns.

The disparity between DCF capital investment planning and divisional control based on book ROI measurements, suggests a need for a re-examination of conventional approaches to divisional planning and control.

The superiority of discounted cash flow (DCF) over other criteria, such as urgency, payback, and book ROI, for measuring the economic worth of capital projects has been convincingly argued many times in the literature. In essence, its superiority is attributable to two principal factors:

1. DCF explicitly recognizes the time value of money.
2. DCF recognizes that the relevant flows are cash flows; hence, capitalization and depreciation policies are irrelevant for capital budgeting decisions except as they affect taxes.

If DCF is truly the most reasonable measure of capital productivity, would it not be prudent to extend this concept to *all* the cash flows of an investment center, such as a division? This would simply involve determining the time-adjusted rate of return (TAROR) for the division's long-range cash forecast.[4]

Let us consider briefly the following simplified illustration. The management of a highly decentralized, diversified corporation is deliberating establishing a new division for the manufacture and sale of a consumer product line not related to any of the company's existing lines—a product line with promising growth

[4] See Billy E. Goetz, *Quantitative Methods: A Survey and Guide for Managers* (New York: McGraw-Hill Book Company, 1965), pp. 271–328, for a detailed discussion of a comprehensive planning budget incorporating the notion of discounted cash flows.

potential. Assume that an initial investment of $700,000 in depreciable assets and $300,000 in working capital is required. The time span used in long-range planning for this prospective division is seven years. Seven years was chosen because management believes it will take that long to accomplish its principal marketing objectives; furthermore, the confidence factor for forecasts beyond seven years decreases substantially. It should be noted here that the length of the planning period not only varies among organizations; but it should also be responsive to changes affecting a given organization over time.[5] The seven-year after-tax cash flow forecast follows:

Seven-Year After-Tax Cash Flow Forecast (in Thousands of Dollars)

Year	*Cash Flow from Operations*	*Depreciable Investment Outlays*	*Depreciation**	*Taxes†*	*Required Increase in Working Capital*	*Cash Transfers Available for or Required from Headquarters‡*
0		$700				
1	$ 382	70	$100	$141	$ 171	$0
2	542	105	110	216	221	0
3	867	175	125	371	321	0
4	712	210	150	281	221	0
5	822	280	180	321	221	0
6	892	385	220	336	171	0
7	1,047	490	275	386	171	0
					$1,497	

* Straight line depreciation, seven-year life, and no residual value for tax and book purposes. Note that since all cash outlays as well as receipts are assumed to take place at the end of the year, depreciation charges are not recorded until the subsequent period.
† 50 per cent of income or cash flow from operations less depreciation.
‡ Cash flow from operations, less the sum of depreciable investment outlays, taxes, and required increase in working capital.

Note that by the end of the seventh year divisional working capital has grown to $1,797,000, i.e., the initial $300,000 working capital investment plus cumulative after-tax cash flows of $1,497,000. The divisional terminal value of $1,797,000 represents a TAROR of 8.7 per cent, since each dollar invested at that rate will yield $1.80 at the end of seven years.[6]

In our example, headquarters has permitted the new division to reinvest all

5 To obtain meaningful results for the proposed divisional planning model, care must be exercised to incorporate a time span of sufficient length to include the major returns expected from large expenditure programs. If the illustration were concerned with an existing rather than a new division, beginning investment should be valued at the current market value of the division.

6 Note the significant increase in working caiptal balances over the seven-year period. Given that working capital requirements are responsive to sales levels, the reader may properly question why the cash flow trend did not correspond to the increases in working capital. This is explained by the fact that, despite significant increases in sales and working capital, cash flows were adversely affected by large expense outlays for product and market development.

its cash flows, but this assumption can be changed to take into account transfers of cash between the division and corporate headquarters. How would TAROR be affected by the transfer of varying sums of cash to headquarters each year? If we make the simplifying assumption that divisional working capital requirements will not be significantly altered during the forthcoming period by the transfer of cash to headquarters, then it is clear that the division must reduce its development expenditures (whether administratively classified as capital or expense projects) by the amount of the transfer. This reduction in cash expenditures will presumably be offset by a related reduction in cash benefits in future periods. The impact of the transfer on divisional TAROR thus depends upon the marginal productivity rate of the funds. Headquarters, on the other hand, can test the estimated sensitivity of divisional TAROR's and, more important, total-firm TAROR to alternative cash-transfer plans that effectively govern the allocation of limited investment funds among divisions.

Let us reconsider the 8.7 per cent TAROR. The value of the division at the end of the seventh year was equated to the forecasted working capital. Working capital, however, represents but one factor in estimating the market value of a division. Going concern valuations take into account customer relations, patents, technology, management skill, and other factors likely to affect future earnings. Consideration of these factors, along with a seven-year history of sound profit performance, would suggest that the division in our illustration has value far beyond its working capital balance. The sensitivity of the TAROR to some alternative valuations at the end of the seventh year is shown below:

TAROR for Various Divisional Valuations at the End of the Seventh Year (in Thousands of Dollars)

Working Capital	*Estimated Additional Value*	*Total Estimated Value*	*TAROR*
$1,797	—	$1,797	8.7%
1,797	$ 500	2,297	12.6
1,797	1,000	2,797	15.8
1,797	1,500	3,297	18.5
1,797	2,000	3,797	21.0

The advantages as well as limitations of the proposed planning model can now be summarized briefly:

1. First and foremost, the proposed model properly measures the productivity of capital, presumably a prime factor in management's long-range system.
2. The proposed model is particularly useful for establishing a judicious balance between short-range and long-range considerations.
3. The model is easy to operate and understand. Indeed its requirement for cash flow data effectively bypass the nagging problems associated with alternative accrual accounting procedures for depreciation, inventory costing, pensions, leasing, and other divisional transactions.

4. *The proposed model is not intended to replace existing planning statements, such as forecasted income statements and balance sheets, but rather to supplement and test the reasonableness of these statements in terms of the capital productivity criterion.*
5. As with other planning models, sensitivity analysis may be employed to test the responsiveness of model results to changes in the variables which are subject to control by division or headquarters.
6. The deterministic "best estimate" model presented earlier does not recognize explicitly the uncertainty surrounding the forecasted cash flows. An explicit recognition of uncertainty—risk analysis—would require a range of estimates and associated probabilities for each estimated cash flow. If the planning team is willing and able to develop the probabilistic input data, the model results can then be expressed as a TAROR probability distribution.

The most carefully conceived plans are inadequate without the exercise of management control. By management control is meant the process by which managers provide for the effective achievement of planned objectives. Perhaps the most important tool serving management control is a sound measurement and reporting system. In a divisional context, such a reporting system generally exists for three main purposes:

1. To guide divisional executives toward actions that are in the best interests of the company
2. To assess the performance of divisional executives
3. To evaluate the productivity of capital invested in the division

Do book ROI systems meet the three proposed objectives served by divisional reporting? Consider the first. That performance measurement systems, formal and informal, influence behavior is a widely recognized phenomenon. Division managers, just as others in the organization, are motivated to optimize those indices upon which their evaluations depend. The attempt to optimize book ROI, however, may not necessarily be in the company's interest. Because book ROI emphasizes current period results, it tends to promote short-range thinking which often discourages growth and the acceptance of reasonable risk.[7]

In assessing book ROI as an index of executive performance, it should be pointed out that the problem of establishing what is controllable investment and what are the controllable elements that govern profit calculation is one concerned with gaining an improved understanding of the complex behavior of organizational systems. This problem is common to all measurement methods developed to appraise executive performance. The most serious defect of book ROI is that it focuses on current period results and, consequently, tells us little about how well the manager is providing for future needs. In short, the current performance of a manager should be measured by current *and* future results. There is no assurance that the division manager who meets or even exceeds his target book ROI is providing wisely for the future growth and profitability of operation.

[7] For examples to illustrate this point see Rappaport, *op. cit.*

Indeed, one is led to suspect a performance measurement system that can reward a manager who pays inordinately for improved short-run results at the expense of strategic longer-run considerations.

How well does book ROI measure the productivity of capital invested in a division? Despite the fact that it is the most common measure of profitability, its use in many situations must be viewed with serious reservations. Earlier, we noted that book ROI suffers from an important deficiency, namely, its neglect of the time value of money. We further noted that DCF models which do, in fact, recognize the magnitude and time pattern of cash flows have found increasing acceptance among those responsible for capital budgeting decisions. We will illustrate the differences between DCF models and book ROI with data from the previous example. For individual years, the book ROI results range from 13.2 per cent to 23.9 per cent. The average book ROI for the seven-year period is 16.4 per cent, as contrasted to the TAROR's previously calculated. The magnitude of the variance between these two measurements will, of course, differ from situation to situation. The important point is that book ROI, and, hence, its variance from TAROR, is affected by certain factors (e.g., accounting policy for capitalization and depreciation) that should have no bearing on the capital productivity measurement.

What are the implications of using a book ROI measurement which improperly estimates a known true yield, i.e., TAROR? The answer lies in the degree to which capital productivity measurements affect corporate as well as divisional decisions. Where such measurements affect the appropriation of funds among divisions, product decisions, or other key decisions concerning the future of divisions, there is a real danger that book ROI measurements may be misleading. This is particularly true when great importance is attached to shorter period book ROI results.[8]

While our comments here have been about companies with relatively independent, autonomous divisions, the Henderson and Dearden reading applies to *integrated,* multidivisional companies. Their contention that the autonomous profit-center concept is a dangerous fiction in integrated firms seems almost beyond controversy, but industrial practice belies that belief. To overcome many of the disadvantages of conventional systems, Henderson and Dearden propose a decentralized control system based on three budgets: a contribution budget, a fixed- and managed-cost budget, and a capital budget.

In the absence of market prices, all revenues from intracompany transfers are priced at standard variable cost, and the budgeted contribution is zero. Henderson and Dearden acknowledge the problem of determining marginal cost under varying volume levels and production conditions, as well as the problem of providing cost improvement incentives for divisions. There is an even more fundamental issue here not discussed by Henderson and Dearden. In order to achieve the benefits of an integrated system, presumably the magnitude and timing of intracompany transfers are planned on a centralized basis, since no division can

[8] For a detailed description of a divisional control system based directly upon the planning model proposed here, see Rappaport, *op. cit.*

make its output decisions independently without jeopardizing the total system. A budgeted contribution of zero takes into account the division's responsibility to control variable costs, but it does not accord recognition to the division's other major responsibility—meeting intracompany transfer quantity and time schedules.[9] Assume, for example, that Division *A* met its budgeted variable costs during the past period but failed to transfer a significant portion of budgeted production to Division *B*. Division *A*'s contribution report would show a zero budget, but who should be held responsible for sales and profits lost by Division *B*, which was unable to supply its external customers?[10] In brief, what is needed here is a performance evaluation model structured on the specific decision model employed to design the integrated intracompany transfer pricing plan.

Dopuch and Drake agree with Henderson and Dearden that, when market prices are not available, marginal costs of production or distribution can be used as a basis for transfer prices. However, Dopuch and Drake properly indicate that marginal costs are adequate only when transfers from a supplying division are limited to a single purchasing division:

> Assuming several divisions desire the output of the supplying division, and the facilities are limited, the opportunity cost of supplying any one division as opposed to another is the greater of the marginal costs of producing the output or the revenue lost by diverting the resource from alternative uses.

The above conditions and substantial fixed facilities available for a number of output alternatives call for an integrated, analytical solution to the resource allocation problem. While mathematical programming holds great promise as an effective tool of planning, its use for performance evaluation in a complex transfer price system may be somewhat more limited. Dopuch and Drake's suggestion that divisional managers' ability to organize efficient means of producing outputs be gauged by comparison with other firms leads to two limiting complications. First, such information may not be available, and second, it may not be directly relevant since it is possible, if not likely, that different firms are organized in significantly different ways to produce a common output. Perhaps a more feasible alternative is the parametric programming approach suggested by Dopuch and Drake. Demski's ex ante, observed, and ex post approach discussed in Chapter 5 appears to be a logical extension of this basic approach. Given the size and complexity of industrial transfer price problems, one must wonder whether a *credible* (to the divisional manager) performance evaluation system that specifies how a given division's departure from a standard affects the optimum value of the total system can be economically developed. Credibility is emphasized, since one of the apparent aims of performance evaluation systems is the positive motivation of those being evaluated.

[9] Quality control is another divisional responsibility to consider.

[10] For one possible approach to this problem, see J. M. Samuels, "Opportunity Costing: An Application of Mathematical Programming," *Journal of Accounting Research,* III (Autumn, 1965), 182–91.

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PART III

BEHAVIORAL ASPECTS OF INFORMATION

9

Motivational Information Systems

THE ROLE OF THE FIRM'S ACCOUNTING SYSTEM FOR MOTIVATION

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An overview of research findings from the behavioral sciences and organization theory as they relate to motivation is presented. A critical examination of accounting systems in light of these findings concludes that responsibility accounting systems are likely to be an incentive for the effective motivation of managers. Depending upon how budgets are developed, they may serve the purposes of positive motivation in certain instances and lead to a reduction in effective motivation in other cases. Participation budgets, a clear expression of goals, and timely performance reports are key factors in increasing positive motivation.

Introduction

Motivating employees to work for the goals of the firm has long been one of management's most important and vexing problems. The search for methods that motivate effectively, that induce the employee to work harder for the firm's goals, led to experimenta-

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tion with a wide diversity of devices.[1] In recent years, several writers emphasized that the firm's accounting system has a direct influence on the motivation of managers.[2] This paper (a) surveys the available findings of research done in the behavioral sciences and organization theory as they bear on motivation and (b) critically examines the accounting system and reports in the light of such findings.

Part I surveys the literature related to motivation and organizational structure and concludes that the decentralized[3] form of organization provides the conditions in which effective motivation can occur. In the light of Part I and other evidence, the accounting system and reports are critically evaluated in Part II. The major conclusions of Part II are that:

1. The empirical research reinforces and justifies the recent emphasis on the virtues of responsibility accounting. Responsibility accounting provides an effective overall aid to decentralization and, hence, while indirect and not as dramatic as some proposed direct uses (such as "proper" budgets or standards), perhaps is more important for effective motivation.
2. The evidence does not support the unqualified use of accounting reports as direct motivating factors. Indeed, there is evidence that the direct use of budgets can lead to a reduction in effective motivation. Nevertheless, there are positive aspects to the direct use of accounting reports.

I. Motivation and Organizational Structure

The motivation of employees may be attempted by the use of a very large variety of techniques, applied in a number of ways. Among these techniques are direct wage incentives, participation schemes, goal setting, and morale boosters. These may be offered directly to the employee by the firm in a centralized fashion (by the personnel department, for example), or indirectly, by the department head in a decentralized firm.[4] Since even a cursory examination of the literature on motivation leads to the realization that the specific techniques of motivation are of almost infinite variety, this paper will concentrate on the problem of application. Indeed, the survey of the literature presented below led the writer to conclude that the organizational structure of the firm is very important for the successful application of motiva-

[1] See M. S. Viteles, *Motivation and Morale in Industry* (New York: W. W. Norton and Company, Inc., 1953).

[2] C. Argyris, *The Impact of Budgets on People* (New York: The Controllership Foundation, 1952). "Tentative Statement on Cost Accounting Concepts Underlying Reports for Management Purposes," *The Accounting Review,* XXXI (1956), p. 188; R. Anthony, "Cost Concepts for Control," *The Accounting Review,* XXXII (1957), pp. 229–34; N. Bedford, "Cost Accounting as a Motivation Technique," *N.A.C.A. Bulletin* (1957), 1250–57; and A. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

[3] *Decentralization,* as used in this paper and in organization theory generally, refers to the vesting of authority and responsibility in the department manager or supervisor for the day-to-day conduct of departmental operations. The department in question need not be physically or organizationally separate from the rest of firm. The title "department manager" and the organizational grouping "department," then, signify any supervisory position and work group for which authority and responsibility over specific tasks are delegated and for which accounting reports are prepared. With this system of organization, the department manager is given the authority to operate his department and supervise his employees as he would do if he were an individual entrepreneur.

[4] In a small firm, these two procedures of application may merge, since the central decision maker is in direct contact with the employees.

tion techniques, especially with respect to the ordinary worker.[5] The influence of organizational structure on motivation, then, is examined below.

Decentralization and Centralization

The organizational structure of decentralization is one in which managers and employees are in direct and continuous contact. This face-to-face relationship facilitates the manager's perception of the needs and goals of his workers. With the authority given him by decentralization, the manager can provide those specific rewards and penalties that are effective for motivating individual workers and groups. Thus, he is in a good position to persuade them to accept the goals of the firm as their own (or as not opposed to their goals) and work to achieve these ends.

In contrast, centralization and large size make perception of the workers' needs difficult. Communication between the decision makers and those who carry out their decisions becomes complicated and subject to more interference ("noise").[6] And, as a study of ten voluntary associations revealed, ordinary members become more passive and disassociated from the central purposes of the organization and leaders become further removed from the activities they plan.[7]

In addition, research at Sears, Roebuck and Co. revealed that organizational size alone unquestionably is one of the most important factors in determining the quality of employee relationships: "the smaller the unit, the higher the morale and vice versa."[8] And, a study of two British motor car factories demonstrated that the size factor affects productivity directly. Significant (though low) correlations were found between output and size, the smaller work groups showing consistently larger output in each factory.[9]

However, the existence of small groups, per se, is not a sufficient condition for motivation. Workers may feel a greater sense of belonging if they work in smaller, more cohesive groups, but they will not necessarily be motivated toward fulfilling the goals of the organization. Some writers, notably Argyris (who has done extensive research at Yale's Labor and Management Center), believe that it is inevitable that the ordinary worker fight the organization. He writes that the organization characterized by "...task specialization, unity of direction, chain of command, and span of control... may create frustration, conflict, and failure for the employee. He may react by regressing, decreasing his efficiency, and creating informal systems against management."[10]

This tendency for informal organizations to be created has been explored extensively.[11] Selznick, for example,

[5] The motivation of managers and other executives similarly is affected by organizational structure. However, since published findings that dealt with the motivation of executives specifically could not be found, the major emphasis in this paper is on the motivation of the ordinary worker.

[6] T. M. Whitin, "On the Span of Central Direction," *Naval Research Logistics Quarterly,* I (1954), 27.

[7] F. S. Chapin and J. E. Tsouderos, "Formalization Observed in Ten Voluntary Associations: Concepts, Morphology, Process," *Social Forces,* XXX (1955), 306–9.

[8] J. C. Worthy, "Organization Structure and Employee Morale," *American Sociological Review,* XV (1950), 173.

[9] R. Marriott, "Size of Working Group and Output," *Occupational Psychology,* XXIII (1949), 56.

[10] C. Argyris, "The Individual and Organization: Some Problems of Mutual Adjustment," *Administrative Science Quarterly,* II (1957), 1.

[11] For example, see C. I. Barnard, *The Functions of the Executive* (Cambridge, Mass.: Harvard University Press, 1938); J. A. March and H. A. Simon, *Organiza-*

writes that "In every organization, the goals of the organization are modified (abandoned, deflected, or elaborated) by processes within it. The process of modification is effected through the informal structure."[12] After reviewing several empirical studies, he concludes that "the day-to-day behavior of the group becomes centered around specific problems and proximate goals which have primarily an internal relevance. Then, since these activities come to consume an increasing proportion of the time and thoughts of the participants, they are—from the point of view of actual behavior—*substituted* for the professed goals.[13]

The Motivation of Small Groups

There also is ample evidence that these informal groups can work to increase or decrease productivity, depending on whether or not the workers perceive that the organization's goals are not contrary to theirs.[14] Two types of procedures have been proposed to cope with this problem. One, the direct approach, involves an immediate attempt by top management to influence the worker through direct wage incentive plans, companywide incentive plans, and group discussions. The other, the indirect approach, gives primary responsibility and authority to the department manager to motivate his workers effectively.

The direct approach is often effective, but it is also difficult to administer successfully. Direct incentive plans are not feasible generally unless a homogeneous product is produced under repetitive conditions.[15] Also, attempts to promote individual increases in productivity usually are disruptive and detrimental to efficiency where the employees' tasks are interrelated.[16] Companywide incentive plans have had a spotty record of success.[17] They seem to work best where there is a long history of trust between labor and management or an unusual person as chief executive of the company.[18] However, efforts to impose companywide incentive plans in other situations have been generally unsuccessful. Group discussions also do not appear to be reliable. A famous experiment conducted in an American plant on the effect of group discussions on productivity and worker acceptance of change

tions (New York: John Wiley & Sons, Inc., 1958); P. Selznick, "An Approach to a Theory of Organization," *American Sociological Review,* VIII (1943), 47–54; and H. A. Simon, *Administrative Behavior* (New York: The Macmillan Company, 1947).

[12] *Ibid.,* p. 47.

[13] *Ibid.,* p. 48. (Emphasis appears in the original.)

[14] For example, see L. Berkowitz, "Group Standards, Cohesiveness and Productivity," *Human Relations,* VII (1954), 509–19; D. Cartwright and A. Zander, "Group Pressures and Group Standards," in *Group Dynamics,* 2nd ed., eds. D. Cartwright and A. Zander (New York: Harper & Row, Publishers, 1960), pp. 165–88; S. Schacter, N. Ellertson, D. McBride, and D. Gregory, "An Experimental Study of Cohesiveness and Productivity," *Human Relations,* IV (1951), 229–38; and W. F. Whyte *et al., Money and Motivation* (New York: Harper & Row, Publishers, 1955).

[15] W. B. Wolf, *Wage Incentives as a Management Tool* (New York: Columbia University Press, 1957).

[16] P. M. Blau, *The Dynamics of Bureaucracy* (Chicago: University of Chicago Press, 1955), Chap. IV; M. Deutch, "The Effects of Cooperation and Competition Upon Group Process," in *Group Dynamics,* 2nd ed., *op. cit.,* footnote 14, pp. 414–48; and E. J. Thomas, "Effects of Facilitative Role Interdependence of Group Functioning," *Human Relations,* X (1957), 347–66.

[17] J. N. Scanlon, "Profit Sharing: Three Case Studies," *Industrial and Labor Relations Review,* II (1948), 58–75.

[18] See J. F. Lincoln, *Lincoln's Incentive System* (New York: McGraw-Hill Book Company, 1946).

produced negative results when replicated in Norway.[19]

The indirect approach makes the informal group's goals synonymous with the organization's goal through effective company leadership of the informal group. The firm then can take advantage of the demonstrated positive relationship between group goals and productivity (cited above).[20] Also, this approach does not rule out the use of direct techniques when and where they are deemed feasible.

The Role of the Department Manager

The indirect approach can be effected most readily in the decentralized firm. The department manager, who is likely to understand and accept the firm's goals,[21] can be assigned the task of leading the informal group. In assigning the department manager this role, the departmentalized firm can take advantage of the probability that the informal grouping of workers will follow the formal department organization. Task specialization and frequent interaction provide this cohesiveness.[22]

It is very important that the organization-oriented manager assume the leadership role, for when he abdicates or is incapable in his role as leader, an informal leader arises.[23] Without a management-oriented leader, the drives of workers for satisfaction are often channeled into nonproductive or destructive practices.[24] This behavior is to be expected, since the effort necessary for high production rarely is satisfying in itself. Indeed, many empirical investigations have shown that there seldom is positive, but occasionally negative, correlation between productivity and job satisfaction.[25]

The factors that are likely to make the department manager an effective leader also are a product of decentralization. Bass, who considers much of the literature on leadership, concludes that the effective supervisor satisfies the needs of his subordinates.[26] Since these needs are diverse, any number of leadership styles have been found to work in a variety of situations. Thus, the organizational structure must allow the manager the freedom and authority to reward his workers. Freedom is necessary so that the manager can adapt his

19 L. Coch and J. R. P. French, Jr., "Overcoming Resistance to Change," *Human Relations,* I (1948), 512–32; and J. R. P. French, Jr., J. Israel, and D. Ås, "An Experiment on Participation in a Norwegian Factory," *Human Relations,* XXX (1960), 3–19.

20 See footnote 14.

21 Research that examined the motivation of managers, as distinct from production workers, could not be found. However, managers are in more direct and continual contact with the firm's policy makers than are ordinary workers. Hence, they are likely to assume the goals of top management (see evidence cited in footnotes 14 and 22). Also, top management can exercise control over the performance and possibly the motivation of department managers through budgets and accounting reports of performance (as discussed below).

22 J. M. Jackson, "Reference Group Processes in a Formal Organization," *Sociometry,* XXII (1959), 307–27. Also reprinted in *Group Dynamics,* 2nd ed., *op. cit.,* footnote 14.

23 R. L. Kahn and D. Katz, "Leadership Practices in Relation to Productivity and Morale," in *Group Dynamics,* 2nd ed., *op. cit.,* footnote 14, pp. 554–70.

24 W. F. Whyte *et al., op. cit.,* footnote 14.

25 A. H. Brayfield and W. H. Crockett, "Employee Attitudes and Employee Performance," *Psychological Bulletin,* LII (1955), 396–424; and R. L. Kahn and N. C. Morse, "The Relationship of Productivity to Morale," *Journal of Social Issues,* VII (1951), 8–17.

26 B. M. Bass, *Leadership, Psychology, and Organizational Behavior* (New York: Harper & Row, Publishers, 1960). The bibliography of this work includes 1155 items.

methods to the particular needs of his group. And, the employees will respond to the demands of the manager only if he has enough influence to make the employees' behavior pay off in terms of actual benefits.[27]

Decentralization also is effective in encouraging the manager to use a style of leadership that promotes effective motivation. It was found in several empirical studies that the fewer the restraints put upon a group (within limits), the more it produced.[28] Kahn and Katz have done extensive research on this aspect of motivation. They find that "Apparently, close supervision can interfere with the gratification of some strongly felt needs."[29] They go on to observe that

> There is a great deal of evidence that this factor of closeness of supervision, which is very important, is by no means determined at the first level of supervision.... The style of supervision which is characteristic of first-level supervisors reflects in considerable degree the organizational climate which exists at higher levels in the management hierarchy.[30]

Thus decentralization, which is characterized by the autonomy of action given the department manager by top management, serves both to allow the managers the necessary freedom and authority needed for motivation and to encourage them to supervise their workers effectively.

II. Accounting Systems and Motivation

Decentralization, which provides the motivational advantages described above, is aided by the firm's accounting system. In fact, many students of decentralization agree with E. F. L. Brech's conclusion (in a review of British experience with decentralization):

> By whatever arrangements and procedures, decentralization necessitates provision for the periodic review of performance and progress and the expression of approval.[31]

This need is met by the firm's accounting system. Top management can afford to give authority to the department manager, since it can control the basic activities of the department with the help of accounting reports of performance. Furthermore, accounting reports and budgets may serve as reliable means of communication, wherein top management can inform the manager of the goals of the firm that it expects him to fulfill.

Responsibility Accounting

More specifically, the findings surveyed above reinforce the recent emphasis on responsibility accounting. In making the smallest areas of responsibility the fundamental building blocks of the accounting system, accountants

[27] D. C. Petz, "Influence: A Key to Effective Leadership in the First Line Supervisor," *Personnel,* XXIX (1952). A similar conclusion is reached by Fiedler for military and sports groups. He concludes that "...leadership traits can become operative in influencing group productivity only when the leader has considerable power in the group." (F. E. Fiedler, "The Leader's Psychological Distance and Group Effectiveness," in *Group Dynamics,* 2nd ed., *op. cit.,* footnote 14, p. 605). Kahn and Katz also reach this conclusion (*op. cit.,* footnote 23, p. 561), as do W. S. High, R. D. Wilson, and A. Comrey, "Factors Influencing Organizational Effectiveness," *Personnel Psychology,* VIII (1955), 368.

[28] R. M. Stogdill, *Individual Behavior and Group Achievement* (New York: Oxford University Press, Inc., 1959), p. 272.

[29] R. L. Kahn and D. Katz, *op. cit.,* footnote 23, p. 560.

[30] *Ibid.,* p. 560.

[31] E. F. L. Brech, "The Balance Between Centralization and Decentralization in Managerial Control," *British Management Review,* VII (1954), 195.

facilitate effective motivation. With a system of responsibility accounting, top management can afford to widen its span of control and allow operating decisions to be made on a decentralized basis. Correlatively, assigning costs to the individual managers who have control over their incurrence is a factor in encouraging these managers to exercise effectively their authority to motivate their supervisees. The managers' performance in this regard is measured by the accounting reports, which are likely to be an incentive for the effective motivation of the managers.

Budgets and Motivation

Indeed, several writers have proposed that accounting reports be used as a direct factor for effective motivation. The most extensive examination of the use of budgets as a tool for motivation was made by Stedry, who measured the effect of various budgets on an individual's level of aspiration as a method of determining the differences in motivation on these budgets.[32] His experiment, in which the subjects attempted to solve problems for which they received budgets and were rewarded for achievement, resulted in the following determinations:

> The experimental results indicate that an "implicit" budget (where the subject is not told what goal he must attain) produced the best performance, closely followed by a "medium" budget and a "high" budget. The "low" budget, which was the only one which satisfied the criterion of "attainable but not too loose," resulted in performance significantly lower than the other budget groups.
>
> However, there is a strong interaction effect between budgets and the aspiration level determination grouping. The group of "high" budget subjects who received their budgets prior to setting their aspiration levels performed better than any other group, whereas the "high" budget group who set their aspirations before receiving the budget were the lowest performers of any group.[33]

After presenting arguments to the effect that firms probably do not operate at optimal efficiency, Stedry concludes that:

> ...it seems at least reasonable to suppose that it is a proper task of budgetary control to be concerned with strategies for constant improvement in performance.[34]

He implies that the budget should be used to motivate department managers. The function of the budget would be to raise the manager's level of aspiration and thereby increase his level of performance, rather than to inform him of top management's goals and decisions.

Stedry briefly notes, but does not really consider, the effects of accounting reports on the setting of aspiration levels. His experiment was deliberately designed so that the subjects would not have knowledge of their performance.[35] The budget then became their primary point of reference.[36] But would this happen where the managers had knowledge of their previous performance to compare with the budget that is supposed to motivate them to new productive heights?

It is likely that department managers can make a fairly accurate estimate of their performance. The experience of time study engineers can be noted, since the setting of a rate for a particular job is analogous to the setting of a budget for a department. In both situations the attempt is made

[32] A. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

[33] *Ibid.*, pp. 89–90.
[34] *Ibid.*, p. 147.
[35] *Ibid.*, p. 71.
[36] *Ibid.*, p. 82.

to motivate the worker to produce more by setting high standards. But, as many articles, texts, and case studies attest, the worker almost always can gauge his performance. The worker generally will fight a "tight" rate by refusing to produce efficiently, because of his fear that the "carrot" will always be pushed ahead every time he attempts to overtake it.[37] There is no reason to expect department managers to be less perceptive than factory workers.

In an actual situation, the department manager probably would compare his estimate of his performance with the budget to see how well he did. This means that the manager would have knowledge of his success or failure. Several experimenters have examined the effect of this knowledge on aspiration levels. Lewin, Dembro, Festinger, and Sears, in an often quoted review and analysis of the literature to 1944, conclude that "...generally the level of aspiration will be raised and lowered respectively as the performance (attainment) reaches or does not reach the level of aspiration."[38]

The effects of success and failure are difficult problems for the would-be budget manipulator. Stedry's findings indicate that a high budget (one technically impossible of attainment) produced the best performance where the subject received it before setting his level of aspiration. The attainable low budget produced the worst results. But in working conditions, assuming knowledge, the high budget probably will result in failure for the department manager and, consequently, in lowering his level of aspiration (motivation) and performance.[39] The budget manipulator, then, must either give the manager false reports about his performance or attempt to set the budget just enough above the manager's perception of his performance to encourage him.

The first alternative, false reports, is a potentially dangerous procedure and is likely to be quite expensive. Performance reports would have to be secretly prepared. This would make accounting data on the department's actual operations (needed for economic decisions) difficult to obtain, since the department manager could not be consulted. Also, this procedure must be based on the assumption that the manager will believe a cost report, even if it conflicts with his own estimates. The validity of this assumption is denied in a study by Simon, Guetzkow, Kozmetsky, and Tyndall:

> Interview results show that a particular figure does not operate as a norm, in either a score card or attention-directing sense, simply because the controller's department calls it a standard. It operates as a norm only to the extent that the executives and supervisors, whose activity it measures, accept it as a fair and attainable yardstick of their performance. Generally, operating executives were inclined to accept a standard to the extent that they were satisfied

[37] See W. F. Whyte *et al., op. cit.,* footnote 14, Chap. 3, "Setting the Rate," for a delightful description of this practice.

[38] K. Levin, T. Dembro, L. Festinger, and P. Sears, "Level of Aspiration," in *Personality and the Behavioral Disorders,* Vol. I, ed. J. McV. Hunt (New York: The Ronald Press Company, 1944), p. 337. A comprehensive test of the hypothesis stated by Lewin *et al.,* which confirmed it, was made by I. L. Child and J. W. M. Whiting, "Determinants of Level of Aspiration: Evidence from Everyday Life," *Journal of Abnormal and Social Psychology,* XLIV (1949), 314. Similar results are reported by I. M. Steisel and B. D. Cohen, "Effects of Two Degrees of Failure on Level of Aspiration in Performance," *Journal of Abnormal and Social Psychology,* XLVI (1951), 78–82.

[39] This may have happened even in Stedry's experiment, since he found that the poorest performance occurred where the subjects determined their aspiration levels before they were given the high budget.

that the data were *accurately recorded,* that the standard level was *reasonably attainable,* and that the variables it measured were *controllable* by them.[40]

The second alternative open to the budget manipulator is rather difficult to effect. The manager's level of aspiration must be measured and *his* perception of his performance level must be estimated. However, measurement of an individual's aspiration level is not a well-developed science. Some fairly successful, though crude, procedures for measuring level of aspiration have been developed. Unfortunately, they depend on the subject's verbal response to questions about the goal explicitly to be undertaken, such as the score expected (not hoped for) in a dart throwing contest.[41] The usefulness of this technique for a work situation is limited, since the employee has an incentive to state a false, low goal and, thus, avoid failure. A more precise measure has been developed by Siegel,[42] but the technique itself restricts it to highly artificial conditions. Thus, it is doubtful that the use of budgets for motivation can be effective except in carefully selected situations.

The direct influence of the budget on motivation may be more effective than is indicated above if the budget is a participation budget, rather than an imposed budget of the type used by Stedry. In a [recent] article, Becker and Green present evidence and arguments to show that participation in budget making in conjunction with the comparison and reviewing process may lead to increased cohesiveness and goal acceptance by the participants.[43] If this goal acceptance is at a higher level than previous goals, the aspiration level of the participants has been raised and should lead to increased production.[44]

Accounting Reports of Performance and Motivation

Budgets are not the only accounting reports that may be used for motivation. Accounting reports of performance also have a direct effect on motivation by giving the department manager knowledge of his performance. Most of the published experiments on this subject consider the effects of knowledge on the learning or performance of physical tasks. However, the general findings reported ought to be relevant to the effect of accounting information on the manager's performance. Ammons surveyed most of the literature in this area (to 1956) and reached the following generalizations that seem applicable to the present problem:

1. Knowledge of performance affects rate of learning and level reached by learning.
2. *Knowledge of performance affects motivation.* The most common effects of knowledge of performance is to increase motivation.
3. The more specific the knowledge of performance, the more rapid improvement and the higher the level of performance.
4. The longer the delay in giving knowledge of performance, the less effect the given performance has.

[40] H. A. Simon, H. Guetzkow, G. Kozmetsky, and G. Tyndall, *Centralization vs. Decentralization in Organizing the Controller's Department* (New York: The Controllership Foundation, 1954), p. 29. (Emphases appear in the original.)

[41] K. Levin, T. Dembro, L. Festinger, and P. Sears, *op. cit.,* footnote 38.

[42] S. Siegel, "Level of Aspiration and Decision Making," *Psychological Review,* LXIV (1957), 253–63.

[43] S. Becker and D. Green, Jr., "Budgeting and Employee Behavior," *The Journal of Business,* XXXV (1962), 392–402.

[44] For a fuller treatment of this subject see the Becker and Green paper, in which is discussed the conditions under which cohesiveness, goal acceptance, and productivity can be lowered as well as increased.

5. When knowledge of performance is decreased, performance drops.[45]

However, overemphasis of departmental cost reports may have undesirable effects, since accounting data often do not measure fulfillment of the firm's goals. Ammons notes that, "It is very important to keep in mind *what* the subject is motivated to do when knowledge of performance increases his motivation. Often he is motivated to score higher, not necessarily to learn the task faster and better. He may then resort to taking advantage of weaknesses in the apparatus, learning habits which are of no value or actually lead to poorer performance when he later attempts to learn a similar task."[46] Overemphasis of accounting reports has been found to result from this behavior.[47] Where the reports became the sole criteria for evaluating performance, managers resorted to such antiproductive techniques as delayed maintenance, bickering over cost allocations, and even falsification of inventories. Thus, recognition of the positive motivational aspects of accounting reports should not lead to the conclusion that they can be used without limits. Indeed, the history of the search for "the key to motivation" indicates that people's needs are too diverse and changeable to be satisfied by any single device or mechanically applied procedure.

Conclusion

Decentralization contributes to effective motivation. The firm's accounting system facilitates decentralization and hence has an indirect but important impact on motivation. The direct use of accounting reports, such as budgets, for motivation can result in reduced performance if the budget is imposed on the department manager. However, a participation budget may be effective in increasing motivation. Also, accounting reports of activities aid motivation by giving the manager knowledge of his performance.

In short, the accounting system facilitates decentralization, which is conducive to effective motivation. Furthermore, the careful use of accounting reports can directly contribute toward effective motivation by expressing goals and by supplying knowledge of performance.

[45] R. B. Ammons, "Effects of Knowledge of Performance: A Survey and Tentative Theoretical Information," *Journal of General Psychology* (1956), pp. 283–90. (Emphasis appears in the original.)

[46] *Ibid.*, p. 280.

[47] See C. Argyris, *op. cit.*, footnote 10; P. W. Cook, Jr., "Decentralization and the Transfer Price Problem," *The Journal of Business,* XXVII (1955), 87; and V. F. Ridgway, "Dysfunctional Consequences of Performance Measurements," *Administrative Science Quarterly,* I (1956), 240–47.

BUDGETING AND EMPLOYEE BEHAVIOR

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In the United States budgeting began with state and local governments. Business adopted imposed budget procedures from government, but, because of some unsatisfactory experiences, it later introduced participation into the budgeting process. Participation is not a panacea; its success depends significantly upon the style of leadership practiced in an organization. The importance of feedback to high levels of performance and morale is emphasized in this reading.

Writing in *Number, the Language of Science,* Tobias Dantzig observed:

> The concrete has ever preceded the abstract.... And the concrete has ever been the greatest stumbling block to the development of a science. The peculiar fascination which *numbers as individuals* have exerted on the mind of man from time immemorial was the main obstacle in the way of developing a *collective* theory of numbers, i.e., an arithmetic; just as the concrete interest in individual stars long delayed the creating of a scientific astronomy.[1]

And so it has been with budgeting, where for some there is still [the] question of whether or not a theory has developed. Business budgeting is a twentieth-century innovation; its development has been characterized by a fragmentary literature and an emphasis on technique. A review of its history indicates that progress has largely been through learning from mistakes—a "cut-and-try" approach. In this paper we will review this history as a background toward an understanding of the relation of the budget to the motivations of those who effect and are affected by it. In a sense this will be an excursion—an attempt to determine "what the behavioral scientists can tell us or find out for us about... the impact [of budgets] on people and on their aspirations."[2] In the process, we will point out that the attempt to make use of motivational factors in the budgeting construct raises many difficult and imperfectly understood problems. Further, we will attempt to explain why the style of managerial leadership is of critical importance in the choice of budget procedures—an issue largely overlooked. Also, we will consider the role played by the communication of performance results and the timing of budget revisions.

In the United States, budgeting by state and local government started with the municipal reform movements around the turn of the century. At the outset, the budget was viewed as an instrument of control—"control over the officers...of administration by placing limitations on their authority

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[1] 4th ed. (New York: The Macmillan Company, 1956), Chap. iii.

[2] David Solomons, "Standard Costing Needs Better Variances," *National Association of Accountants Bulletin,* XLIII (December, 1961), 30.

to spend."[3] These early budgets were, and for the most part still are, authorizations to spend—appropriations—for particular "objects of expenditure," such as personal services, commodities, travel, and the like. The appropriation was the "upper limit" much like a thermal control on a furnace—when the limit is reached the fuel, or, in the fiscal sense, the money is stopped. The upper limit was imposed through the approving of the budget by the governing body—the board, the council, the legislature, etc.

These governmental budgeting procedures provided for a second type of control—a restraint control. Each claim presented had to be approved for payment by the chief financial officer. The question of "what is a legal or bona fide obligation?" was resolved by considering (1) whether the budget document provided for such an expenditure, (2) whether sufficient funds were left in the appropriation to pay the claim, and (3) whether the necessary documents were on hand. To know if the remaining appropriation was sufficient, fairly elaborate records were maintained. To these were posted the dollar amounts of issued purchase orders as well as the specific expenditures. Both types of transactions reduced the "available" balance. This was a practice of *clerical* control—a technique employed to insure the completeness of record and one that is still unique to governmental accounting (with the possible exception of retail "open-to-buy" records). To the extent that interim reports were prepared and distributed to department heads, rudimentary *communicative* control was practiced.

Governmental purposes were served well enough by these budget procedures. Revenue and expense forecasts were relatively simple. Because changes were not contemplated, the budgets were for fixed amounts for the designated time period. Where actual revenues fell short of the estimates, unilateral demands to cut expenditures by a designated pecentage were issued—sometimes by resort to payless paydays.

Early business budgeting largely imitated governmental practice and technique. It began with "imposed" budgets[4] and the obvious controls—limit, restraint, clerical, and communicative. During the early and middle 1930's, it became fashionable to speak of "budgetary control" and to view the budget as both (1) a financial plan and (2) "a control over future operations."[5] Also in the thirties, the inadequacies of the static budget became obvious when business activity took a sharp downturn and profits disappeared.[6]

A budget form that provided for intraperiod changes in the level of sales or manufacturing was introduced and was called a *flexible* or *variable* budget. It attempted to provide "bench mark" numbers for a range of contemplated activity.

Primarily, budgetary control has been the attempt to keep performance at or

[3] Frederick A. Cleveland, *Chapters on Municipal Administration and Accounting* (London: Longmans, Green & Co., Ltd., 1909), p. 72.

[4] Imposed budgets have been characterized as ones "dictated by top management without the full participation of the operating personnel." [R. N. Anthony, "Distinguishing Good from Not-So-Good Accounting Research," in *Proceedings of the 22nd Annual Institute on Accounting* (Columbus: The Ohio State University, 1960), p. 68.]

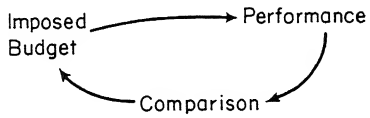
[5] Eric Kohler, *A Dictionary for Accountants* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1957), p. 75.

[6] F. V. Gardner, "How About That 1935 Operating Budget?" *Factory Management and Maintenance* (November, 1934); C. E. Knoeppel and E. G. Seybold, *Managing for Profit* (New York: McGraw-Hill Book Company, 1937), p. 206.

within the acceptable limits of the predetermined flexible plan. In a sense the plan controls—but for how long? And how is the plan to be modified?

Budget Periodicity

The recurring cycle of early governmental and business budgets was simple. The budgets were imposed; there was performance, and the comparison of the performance against the budget influenced the next budget. The cycle could be depicted as follows:



Ordinarily, the budget period was one year or two. The comparison of performance and budget often had curious results on the subsequent budget. Where expenditure was less than budget, there was a tendency to revise the subsequent budget downward. As a result, managers would engage in a spending spree the last few weeks of an appropriation year to avoid being cut down next year.

The budget period in business has also been calendar oriented—the quarter or twelve-week period extended twelve or fifteen months. Ordinarily, budget revisions are restricted to future periods. Later in the paper we will discuss reasons for cycling budget revisions on a basis other than the calendar.

Budget Modification

By 1930 it was recognized in business circles that imposed budgets "resulted in some dissatisfaction and advice was given to prepare them in the departments and have them revised or edited in the central offices."[7] Thus *participation* was introduced into the budgeting construct. It has been said that the "real values of participation at all management levels..., aside from better planning are the psychological values that accrue as the result of participation. A high degree of participation is conducive to better morale and greater initiative."[8]

There is some evidence of the extent (and degree) to which participation is currently employed in business. Sord and Welsch interrogated managements of thirty-five companies to determine the level at which principal budget objectives were developed. No companies said they used totally imposed budgets. Six firms (17 per cent) prepared objectives at higher levels and allowed subordinate managers to consider and comment on them before final adoption. Twenty-nine firms (83 per cent) said they requested subordinate managers to prepare their own goals and objectives for review and approval at higher levels.[9]

Theirs, obviously, was a very small sample. Furthermore, it is questionable that the interrogatories used did, in fact, investigate participation. As Chris Argyris discovered, there is such a thing as "pseudo-participation." "That is, participation which looks like, but is not, real participation."[10]

Participation may have great value in improving budgets by drawing together the knowledge diffused among the participants, although we do not treat this objective here. Our interest

[7] *Budgetary Control in Manufacturing Industries* (New York: National Industrial Conference Board, 1931), p. 52.

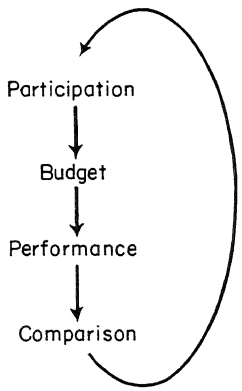
[8] B. H. Sord and G. A. Welsch, *Business Budgeting* (New York: The Controllership Foundation, 1958), p. 97.

[9] *Ibid.*, p. 95.

[10] *The Impact of Budgets on People* (New York: The Controllership Foundation, 1952), p. 28.

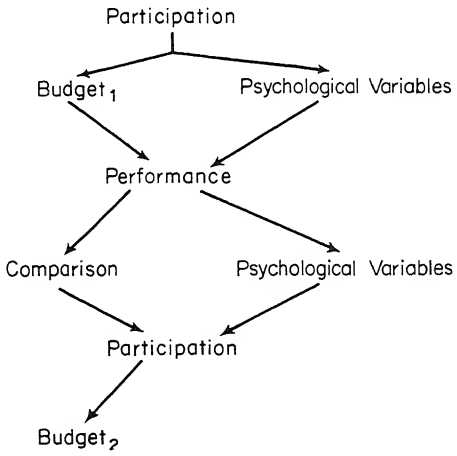
is in participation as a useful technique for dealing with the psychological problems of employee satisfaction, morale, and motivation to produce; that is, the belief that increased participation can lead to better morale and increased initiative. The evidence supporting this belief will be evaluated, as well as other psychological effects associated with participation that may be of even greater importance. But first the question: What is participation? We will use the following definition: Participation is "defined as a process of joint decision-making by two or more parties in which the decisions have future effects on those making them."[11]

A collateral question is: How does the introduction of participation affect the budget cycle? At first glance, it seems that the chart would appear as follows:



However, we believe this is too simple. Participation adds a separate "psychological path." Participation is *not* a single-value variable but rather is a concept encompassing several explicit variables. Instead of a simple cycle we have a sequence that might be depicted as follows:

[11] J. R. P. French, Jr., J. Israel, and D. Ås, "An Experiment on Participation in a Norwegian Factory," *Human Relations,* XIII (1960), 3.



In paragraphs that follow we will attempt to identify these unspecified psychological variables by examining what we consider to be the relevant available research results. Before proceeding, it is imperative to make one fundamental point: *Participation is not a panacea.*[12] Indeed, there is evidence to suggest that it is inappropriate in certain "environments." When participation is employed, the concept of control, as outlined above, requires modification. Instead of the budget being the plan to which performance is conformed, compared, and evaluated irrespective of changes in environment (other than those provided for in the flexible budget), the plan is influenced, at least in part, by the environment. That is, control limits and informs those operating under the budget; in turn, they determine and limit the succeeding budget.

Participation, Morale, and Productivity

In an industrial setting Coch and French investigated the effects of prior

[12] A useful discussion—"Participation in Perspective"—appears in Douglass McGregor, *The Human Side of Enterprise* (New York: McGraw-Hill Book Company, 1960), Chap. ix.

participation on production after work changes were introduced.[13] Difficulty of work and percentage of work changes were equated for a no-participation group (NP), for participation by representation (PR), and for a total participation (TP) group. With a prechange standard of sixty units per hour, after relearning, the NP group reached a level of fifty units per hour; the PR group sixty units per hour; and the TP group sixty-eight units per hour, or an improvement of about 14 per cent over the standard rate. Another important finding was that 17 per cent of the NP group quit their jobs in the first forty days after the change, and the remaining members of the group filed grievances about the piece rate, which "subsequently was found to be a little 'loose'." There was one act of aggression against the supervisor from the PR group, none from the TP group, and no quits in either the PR or TP groups.

If employee turnover and stated grievances can be taken as a measure of morale, then it seems clear that the two groups that participated in the initiation of change were better disposed toward their job situations than was the no-participation group.

Based only on this study one cannot decide if participation directly increased incentive to produce, as measured by subsequent productivity, or only improved morale, which in turn led to increased motivation. This is a point worth considering, since morale is not perfectly correlated with productivity.

An inference about this relationship can be drawn after examination of a study by Schachter *et al.* on group cohesiveness and productivity.[14] (Group cohesiveness is usually defined as attraction to the group—desire to become or remain a member—and reluctance to leave the group. Another way of looking at cohesiveness might be the amount of "we" feeling generated in an individual as a result of his association with others.) Schachter and his associates experimentally created high and low cohesiveness in two groups. A task was chosen in which output could be easily measured. In half of each group subjects were individually given instructions designed to induce production at a high rate, the other half instructions designed to induce production at a low rate. It was found that group cohesion and acceptance of induction were significantly related. The high cohesive groups more frequently accepted induction than did the low cohesive groups. This was especially true of the negative induction, or "slowdown" situation.

The Coch and French study suggests that morale and/or productivity are enhanced as a result of employee participation in the initiation of change. The Schachter *et al.* study suggests that with participation held constant (all groups worked under constant conditions) change in productivity is related to group cohesiveness. Cohesiveness, it can be seen from the definition, is related to morale. Morale is most frequently defined as satisfaction with one's job, supervisors, and working associates. It has also been defined as the *degree* to which an employee identified himself as part of the organization. In either case, morale and cohesiveness with a group imply some similar reactions and attitudes toward an organization or group.

Since participation affects morale (cohesiveness) and productivity, but cohesiveness without participation af-

[13] L. Coch and J. R. P. French, Jr., "Overcoming Resistance to Change," *Human Relations,* I (1948), 512–32.

[14] S. Schachter, N. Ellertson, D. McBride, and D. Gregory, "An Experimental Study of Cohesiveness and Productivity," *Human Relations,* IV (1951), 229–38.

fects production, the most likely conclusion is that cohesiveness is dependent on participation but that changes in productivity are more directly related to cohesiveness.

Elements of Participation: Process and Content

Let us consider participation as conceptually divisible into process and content. Process means the *act* of participating with the possible consequences stemming from the act; content is the *discussion topic* toward which are generated the positive or negative attitudes. The *act* of participating enables the participants to know one another, communicate and interact with one another—conditions that easily can lead to increased cohesiveness. As we have seen, however, increased cohesiveness also can result in lower production if that is the sentiment of the cohesive group. Thus, it becomes clear that the content of participation is an important determinant of final production levels. What should the content consist of and what should it accomplish? These questions can be answered on the basis of some data on group decision-making collected by Kurt Lewin and his students.[15] One experiment was designed to induce housewives to use previously unused foods (sweetbreads, etc.). Positive communications describing the foods were presented to two groups—one by the lecture method, the other by a group discussion method. A subsequent check revealed that 3 per cent of the women who heard the lectures served one of the meats never served before, whereas after group discussion, 32 per cent served one of the meats. This experiment was repeated with a different leader, different groups, and a different food—milk—and yielded essentially similar results.

As compared to individual instruction and the lecture method, group discussion was superior in inducing change—a result attributed to the hesitancy of individuals to accept goals that depart from the group standard. (Psychological nonacceptance of a goal by an individual virtually precludes its attainment by him.) The group discussion method allows the group member to assess the standards of all other members, so that if the group apparently accepts a change, he too can accept it and retain his group membership.

It is clear that the content of participation should be directed toward setting a new goal with discussion of a sort sufficient to enable each participant to realize that the goal is accepted by the others in the group. The fulfillment of these conditions could serve as a definition of successful participation by (1) providing the opportunity for enough interaction so that a cohesive group can emerge and (2) directing the interaction so that each participant's analysis of the content will enable him to accept as his own those goals adopted by the group. Thus, we can see that the process and content of a participation program interact and that such interaction can lead to one of several outcomes:

1. High cohesiveness with positive attitudes (goal acceptance), a condition of maximally efficient motivation
2. Low cohesiveness with positive attitudes, an unlikely but possible condition that probably would result in efficient performance
3. Low cohesiveness and negative attitudes, a condition resulting from unsuccessful

[15] "Studies in Group Decision" in *Group Dynamics*, eds. D. Cartwright and E. Zander (New York: Harper & Row, Publishers, 1956), pp. 287–88.

participation that would tend to depress production within the limits of the integrity or conscience of each individual
4. High cohesiveness and negative attitudes, the occurrence most conducive to a production slowdown.

Level of Aspiration and Performance

Ideally, in the budgeting process, participation results in a plan of action including a proposed amount of accomplishment and an estimate of the costs to achieve it. If participation has been successful, then these proposed levels of cost and accomplishment are accepted as goals by the participants. In effect, these projected levels of achievement become the levels of aspiration of the managers of the organization. (In a smoothly running organization the managers induce acceptance of the same levels of aspiration in the members of their departments.)

Level of aspiration has been defined in the psychological literature as a goal that, when just barely achieved, has associated with it subjective feelings of success; when not achieved, subjective feelings of failure.[16] From an extensive review of the literature Child and Whiting summarize many findings into five conclusions:

1. Success generally leads to a raising of the level of aspiration, failure to a lowering.
2. The stronger the success the greater is the probability of a rise in level of aspiration; the stronger the failure the greater is the probability of a lowering.
3. Shifts in level of aspiration are in part a function of changes in the subject's confidence in his ability to attain goals.
4. Failure is more likely than success to lead to withdrawal in the form of avoiding setting a level of aspiration.
5. Effects of failure on level of aspiration are more varied than those of success.[17]

Recently Stedry has utilized this psychological variable in an attempt to establish some relations between level of aspiration, imposed budgets, and subsequent performance.[18] Stedry... may have overlooked some of the relevant psychological literature. Seemingly he selected an inaccurate method of measuring aspiration level which weakens his several conclusions and recommendations. For his measure of level of aspiration, Stedry asked his subjects to express what they "hoped to achieve" on the next set of problems. Festinger found that the *D* score (the difference between performance and aspiration) was greater between performance and expressions of "like to get" than between performance and expressions of "expect to get."[19] Diggory found the correlation between "hope" statements before and after failure significantly higher than statements of expectations before and after failure.[20] In other words, "hope" and "expect" represent different attitudes. Since level of aspiration is defined as the goal one explicitly undertakes to reach rather than the goal one hopes to achieve, it seems clear that Stedry's

[16] K. Levin, T. Dembo, L. Festinger, and Pauline Sears, "Level of Aspiration," in *Personality and the Behavior Disorders,* I, ed. J. McV. Hunt (New York: The Ronald Press Company, 1944), pp. 333–78.

[17] J. L. Child and J. W. M. Whiting, "Determinants of Level of Aspiration: Evidence from Everyday Life," in *The Study of Personality,* ed. H. Brand (New York: John Wiley & Sons, Inc., 1954), pp. 145–58.

[18] Andrew C. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

[19] L. Festinger, "A Theoretical Interpretation of Shifts in Level of Aspiration," *Psychological Review,* XLIX (1942), 235–50.

[20] J. C. Diggory, "Responses to Experimentally Induced Failure," *American Journal of Psychology,* LXII (1949), 48–61.

conclusions are based on an inaccurate measure of his major variable. Subsequently, Stedry has indicated his belief, based on questionnaire information, that his "subjects appeared... to have given the right answer to the wrong question."[21] In any event, his attempt is valuable heuristically because it highlights a possible relation between budgets, budgeting, and human motivational performance.

We have already hypothesized a relationship between participation and the formation of levels of aspiration. There remains a specification of the effects of level of aspiration on the remaining segments of the budget cycle.

After the budget has been adopted, the attempt to translate it into behavior constitutes the performance part of the cycle. The degree of effort expended by members of the firm as they attempt to achieve budgeted goals is partially dependent upon their levels of aspiration. Maximum effort will be exerted to just reach an aspired-to goal. In fact, according to level of aspiration theory if, for example, five units of effort are required to reach goal $x-3$, ten units to reach goal $x-2$, fifteen units to reach goal $x-1$, and twenty-five units to reach goal x—the level of aspiration goal—an individual will expend the disproportionate amount of energy to achieve at level x to derive that subjective feeling of success. Thus we can see how a budget that is partially derived through a successful program of participation can result in greater expenditure of effort on the part of employees to reach goals specified in the budget.

Such expectations are not without foundation, of course. Bayton measured the levels of aspiration of three hundred subjects of roughly equivalent ability prior to their performance on seven arithmetic problems. He found that subjects with higher levels of aspiration followed with higher performance.[22] From a finding of this sort one cannot conclude that greater motivation to achieve is associated with the level of aspiration goal, but it is well known that increased motivation leads to increased effort, a condition usually followed by an increase in performance. We can thus find indirect support for our contention. Another bit of evidence may illustrate the point further. Siegel and Fouraker set subjects to bargaining under bilateral monopoly conditions.[23] With no control of levels of aspirations, the subjects maximized their joint profits and split the profits nearly equally. However, when high and low levels of aspiration were induced into the bargaining pairs (despite the fact that a better bargain meant more money for the subject), those with a low level of aspiration gained only about one-third of the joint profits. Thus, it seems clear that level of aspiration not only describes a goal for future attainment, but also it partially insures that an individual will expend a more-than-minimum amount of energy, if necessary, to perform at or above that level.

Depending, then, on the conditions under which a budget is drawn, the budget can act as a motivating force and can induce better performance from the members of the organization. On the other hand, the budget can specify aims and goals so easy of attainment that the organization's members

[21] Stedry, "Aspiration Levels, Attitudes, and Performance in a Goal-oriented Situation," *Industrial Management Review,* III (Spring, 1962), 62.

[22] J. A. Bayton, "Interrelations between Levels of Aspiration, Performance and Estimates of Past Performance," *Journal of Experimental Psychology,* XXXIII (1943), 1–21.

[23] S. Siegel, L. Fouraker, *Bargaining and Group Decision Making* (New York: McGraw-Hill Book Company, 1960).

will be induced to produce at less than their usual capacity.

After the performance phase of the cycle a comparison is made between the costs and income previously predicted in the budget and the actually attained income and costs. We are not here concerned with how the comparison is made but rather with its utilization, since that may have considerable effect on employee behavior and morale.

Much has been written on the effect of communication within an organization. With reference to the comparison, or control, function of the budget, the use or misuse of communication can be critical especially when viewed in the context of participation and level of aspiration.

First and foremost, it is imperative for each participant to know whether he should feel subjective success or failure. If he is not informed of the results of the comparison, he cannot know whether his striving for a particular level was worthwhile or not. Nor can he, in turn, pass on the word to his subordinates in whom he induced specific levels of aspiration. They, too, will not know whether to feel success or failure. We can see that communicating knowledge of results acts, in this case, as reward or punishment. It can serve either to reinforce or extinguish previous employee behaviors. Where subjects were given a learning task and provided knowledge of results, learning increased; but when knowledge of results was withheld, performance fell; that is, learning not only stopped but performance was decreased.[24] In discussing these results, Munn argued that "the rapid drop in performance which followed this point may be attributed to the loss of motivation which came with withdrawal of knowledge of results, not from forgetting what had been learned up to this point."[25]

Failure to communicate knowledge of results adversely affects not only performance but also morale. Leavitt and Mueller, in an investigation of effects of varying amounts of feedback, found that task accuracy increased as feedback increased. They also found that zero feedback is accompanied by low confidence and hostility, while free feedback is accompanied by high confidence and amity.[26]

The question may now be asked: "So what if the employees don't know how they did? They already performed and the profit is recorded." The answer obviously concerns the effects this lack will produce on subsequent behavior and, more specifically, on the goals to be set in the succeeding budget.

The next budget will be affected because omitting feedback not only precludes certainty regarding a previous level of aspiration but also affects the subsequent level of aspiration. Most generally an individual will raise his level of aspiration after success and lower it after failure.

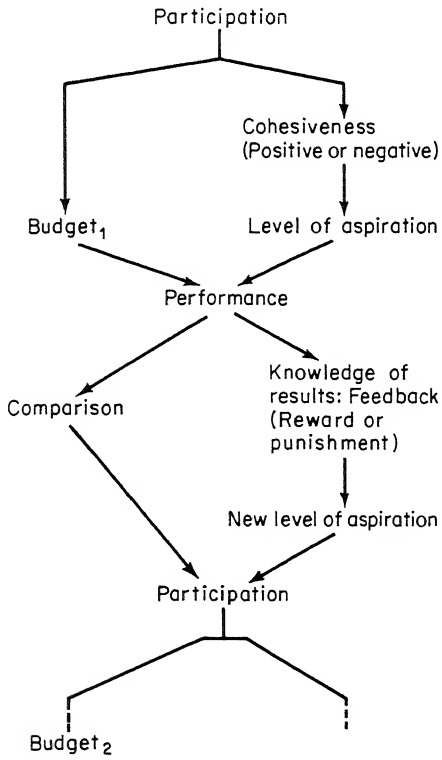
In the budgeting cycle, after the comparison phase, the new budget is started. The participating supervisors bring to the new participation situation all their new aspirations resulting from past feelings of success or failure. If they have been deprived of a rightfully achieved feeling of success, their subsequent aspirations are likely to be lowered. This could result either in a less efficient budget, that is, lower goals than could easily be achieved or,

[24] J. L. Elwell and G. C. Grindley, "The Effect of Knowledge of Results on Learning and Performance," *British Journal of Psychology,* XXIX (1938).

[25] N. L. Munn, *Psychology* (Boston: Houghton Mifflin Company, 1946).

[26] H. J. Leavitt and R. A. H. Mueller, "Some Effects of Feedback on Communication," *Human Relations,* IV (1951), 401–10.

after disagreeable argument, an imposed budget from an adamant management. In the first case succeeding performance will be unnecessarily low, in the second, participation will be ineffectual with the possible result of poor performance and, almost certainly, lower morale. The *proper* budget cycle then is really a dual, interacting sequence of budgeting and psychological events. It can be depicted as follows:



A successful participation budget does two things: (1) it induces proper motivation and acceptance of specific goals and (2) it provides information to associate reward or punishment with performance. These lead to new aspirations and motivations that set the stage for the next participation budget.

Conclusions

An understanding of the psychological variables stemming from participation is valuable, perhaps, for its own sake, but it is hardly likely to provide concrete assistance in a decision to institute such a program. We have seen that participation can lead to either increased or decreased output. It is not unlikely that the setting in which participation occurs is one determinant of the production outcome. Some organizations can be characterized as operating under relatively authoritarian leadership. By definition, participation is essential to democratic process and very probably is antithetical to an authoritarian organization. To illustrate the latter, assume that the various department heads participate in the decision-making process and prepare a budget, only to have it rejected by upper management without explanation other than that a more satisfactory budget is necessary. The best prediction here is that the participating group will be highly cohesive and hold negative attitudes toward management, a precondition to lowered output.

It is also likely that, under authoritarian management, status differences will be rigidly adhered to. If the participants in the budgeting process occupy different status levels, influence on decicions will be directly related to status—the more status, the more influence. Status differences would probably mitigate against high cohesiveness. Presumably status differences that did not affect the decision-making process would not preclude either a cohesive group or positive goal acceptance, especially if the occupants were secure in their positions or perceived the possibility of upward mobility.[27]

[27] Harold H. Kelley, "Communication in

We do not wish to enter the controversy over the relative merits of various styles of leadership but merely wish to point to some possible limitations on the use of participation. In order to be successful, the participants must participate, that is, must have influence on the adopted decisions. If participation can be achieved under more or less authoritarian conditions, it is likely to be effective, just as it can be undermined (by disregard) with democratic leadership. Only management itself can determine whether it is worthwhile to initiate or continue the participation segment of the budgeted cycle.

At any rate, presuming an organization has determined that it can benefit from participation, are the psychological effects such that participation simply can be "grafted" onto existing procedures or are other changes necessary? Or indeed, if no changes are necessary, are there any that can be made so that efficiency, motivation, and productivity will be enhanced?

Suggested changes in budgeting are not difficult to find. Stedry, recognizing the possible motivating forces produced by budgets, seems to suggest that "phony" budgets be prepared while the real budget is kept secret.[28] The phony ones would be designed to induce maximum motivation through a manipulation of level of aspiration. This plan would require different phony budgets for each department and, indeed, for each individual. If different budgets are viewed as discriminatory and unfair devices, company morale might suffer. Further, if already disgruntled employees learn that they were striving to attain phony goals, the effectiveness of future budgets, real or phony, might be seriously impaired.

A knowledge of the effects of level of aspiration may lead to changes designed to increase employee motivation and output. The budget cycle characteristically is tied to an arbitrary time schedule. Even with no other information, this is defensible logically and perhaps economically as well. If however, the budget is to be used as a control device (in the sense of prohibiting excessive expenditures) as well as a motivating device, then it clearly should be tied to the level of aspiration cycle rather than to a time schedule. We know that success leads to a rising level of aspiration and, generally, failure to a lowering. Failure can also result in "leaving the field," that is, psychological or physical withdrawal from the goal-oriented environment.

It is suggested here that much more frequent comparison of performance and budget be made, including feedback to the employees of the results of the comparison. This recommendation is made for the following reasons: (1) If the performances meet or slightly exceed expectation, then level of aspirations will rise and budgets can and should be revised; otherwise employees will perform at the budget level when they could be performing at a higher budget level. Maximum efficiency can only be achieved by revising the budget upward. (2) If performances are just slightly below the budget expectations, budget changes are not necessary, but feedback is so that employees will continue to strive for the budget goals. (3) If performances are well below the budget, it may be well to revise the budget downward. If such revision is not made, employees' level of aspiration will fall, the budget will be viewed

Experimentally Created Hierarchies," *Human Relations,* IV (1951), 39–56.

[28] A. C. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960), pp. 5, 17, 41–42, and 71. Stedry does not use the term "phony."

as unattainable, and output will fall. The danger here is that levels of aspiration and output may fall much more than is necessary. If the budget is revised downward just enough so that it is perceived as being attainable, then maximum output will be achieved again.

BUDGETING AND EMPLOYEE BEHAVIOR: A REPLY

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Several studies are cited to support the view that organizations with authoritarian structures are more effective in task performance than democratic ones. Participation, it is argued, does not necessarily lead to beneficial effects, since these effects are heavily conditioned by personality and environmental factors. Stedry counters the Becker and Green contention that he selected an inaccurate method of measuring aspiration level in one of his earlier experiments.

In their article "Budgeting and Employee Behavior," Selwyn W. Becker and David Green, Jr.[1] present an amalgamation of psychological and accounting theory. The authors are concerned with the problem of employee response to budgetary modification and state that, for them, a major "interest is in participation as a useful technique for dealing with the psychological problems of employee satisfaction, morale, and motivation to produce; that is, the belief that increased participation can lead to better morale and increased initiative" (p. 394).

Implicitly in this quotation and explicitly in the following discussion they state that as fundamentals of their approach (1) "*participation is not a panacea* [italics in original]. Indeed, there is evidence to suggest that it is inappropriate in certain 'environments,'" and (2) that "participation is *not* a single-value variable but rather is a concept encompassing several explicit variables" (p. 395). It is not clear how, reasoning from these fundamentals, they arrive at a set of conclusions which, among other statements, includes:

> A successful participation budget does two things: (1) It induces proper motivation and acceptance of specific goals and (2) it provides information to associate reward or punishment with performance. These lead to new aspirations and motivations that set the stage for the next participation budget [p. 401].

The difficulty may lie in their assumptions about possible relationships between morale and motivation as they affect productivity and between participation and productivity within a framework of an organizational leadership style.

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[1] *The Journal of Business*, XXXV (October, 1962), 392–402. Page references to this article are given in parentheses in the text.

This commentary, while upholding the two fundamental points, questions the assumptions and the conclusions which rest upon them. For the moment, let us take "participation is not a panacea" and the following quotation:

> We do not wish to enter the controversy over the relative merits of various styles of leadership but merely wish to point to some possible limitations on the use of participation. In order to be successful, the participants must participate, that is, must have influence on the adopted decisions. If participation can be achieved under more or less authoritarian conditions, it is likely to be effective, just as it can be undermined (by disregard) with democratic leadership. Only management itself can determine whether it is worthwhile to initiate or continue the participation segment of the budgeted cycle [p. 401].

In spite of some possible ambiguity in the above statement, it seems almost impossible for them to advocate participation without entering the leadership style controversy. Indeed, they had earlier stated, "By definition, participation is essential to democratic process and very probably is antithetical to an authoritarian organization" (p. 401). In view of the clear implications provided by Becker and Green that participation should be a part of budgeting practice (even though qualified occasionally to the effect that it should *really* be participation and that other changes—apparently in leadership style—may be necessary for success), it would seem to be of value to discuss some of the relevant literature.

Leadership Styles and Productivity in Brief

While the evidence is generally mixed, several studies support the view that organizations with authoritarian structures are more effective in task performance than democratic ones. Experiments by Leavitt using the network apparatus developed by A. Bavelas indicated higher morale but lower productivity where communication patterns for problem solution offered more organizational freedom and individual autonomy—that is, democratic prototypes—than in more hierarchically structured patterns—that is, authoritarian prototypes.[2] Also using the Bavelas networks, Guetzkow and Dill found that part of learning to perform the experimental task was the development of a hierarchical (more authoritarian) structure with few communication channels and a rationalized leader from a less structured (more democratic) communication pattern with more avenues of communication.[3] Further experimentation of Leavitt (unpublished) indicates that those groups which began with a less structured organization, although they in effect chose their own leader, never "caught up" in performance with those groups which had initially been more hierarchically organized.

Such evidence is not, however, restricted to the laboratory. Morse and Reimer varied closeness of supervision of clerical workers.[4] One group's supervision was altered to a looser, more autonomic structure, while a second group's supervision was made closer and more detailed. While in the

[2] H. J. Leavitt, "Some Effects of Certain Communication Patterns on Group Performance," in *Readings in Social Psychology*, eds. Eleanore E. Maccoby, T. M. Newcomb, and E. L. Hartley (New York: Holt, Rinehart & Winston, Inc., 1958), pp. 546–63.

[3] H. Guetzkow and W. R. Dill, "Factors in the Organizational Development of Task-oriented Groups," *Sociometry*, XX (1957), 175–204.

[4] Nancy Morse and E. Reimer, "The Expermiental Change of a Major Organizational Variable," *Journal of Abnormal and Social Psychology*, LII (1956), 120–29.

first group the workers had higher morale and exhibited more involvment and commitment in their work than the second, marked improvement in productivity was observed in both groups with the more closely supervised group's improvement significantly *greater*. Several surveys have indicated that successful supervisors are more frequently observed among those who spend more time in supervisory activities, in particular in planning and skilled tasks, than in working with the men or other nonsupervisory duties.[5]

Further corroboration may be obtained from the work of Fiedler, who found in a variety of situations that leaders who remain distant and aloof from their subordinates are more successful than their counterparts who form close personal ties with (i.e., "relate to") their work groups.[6] While these results are again in the form of survey data, they are somewhat stronger than most inasmuch as the aloofness score utilized might be interpreted as a measure of a "conditioning variable" whose relative size remains fairly consistent across individuals in a variety of situations—that is, there are "high aloofness people" and "low aloofness people." In any event these studies cast serious doubt on theories of management which rely excessively upon improvement of the personal relationship of supervisor and subordinate. Such results, coupled with evidence cited above of the apparent efficacy of time spent in planning and supervising rather than working with men, clearly leads us to look beyond the man-manager relationship for a viable theory of effective supervision.

Morale and Productivity

Another assumption which appears vital to Becker and Green's discussion is the effect of various budgeting practices on morale.[7] The social-psychological evidence of a relationship between morale and productivity is drawn almost exclusively from survey data, thus making it impossible to determine whether (or in which situations) (1) high morale causes high productivity, (2) high productivity causes high morale, or (3) both high morale and high productivity are caused by one or more other environmental contributors. The almost ubiquitous inference of the first causal determination is unjustified by the form of the evidence.[8] It is also of interest that the

[5] Cf. R. L. Kahn and D. Katz, "Leadership Practices in Relation to Productivity and Morale" in *Group Dynamics,* 2nd ed., eds. D. Cartwright and A. Zander (New York: Harper & Row, Publishers, 1960), pp. 554–71. It should be noted that the evidence presented is generally gleaned from survey data. E.g., although some consensus among the studies cited would tend to indicate that foremen who have "freedom" to plan ahead are higher producers, it is not clear whether this freedom reflects a recognition by their supervisors of their abilities or the converse. Also a statement (p. 563) that "high producing supervisors were predominantly employee-identified" would seem to conflict with the evidence (pp. 556–58), of the positive correlation of productivity with the amount of time spent supervising and planning—which would reflect, by contrast, a greater managerial orientation—than with time spent working with men. The difficulty here seems primarily methodological. The difficulties inherent in attempting to draw causal conclusions (albeit carefully) from first-order correlations of survey data are signal.

[6] F. E. Fiedler, *Leader Attitudes and Group Effectiveness* (Urbana, Ill.: University of Illinois Press, 1958).

[7] Although they caution us that (p. 396) "morale is not *perfectly* correlated with productivity" [italics mine], they seem to imply (in direct references on pp. 394, 395, 396, 399, 400, and 402) its beneficial effects and improvement through feedback and/or participation.

[8] For a most thorough review of this evidence see R. Likert, *New Patterns of Management* (New York: McGraw-Hill Book

study of Morse and Reimer revealed an inverse relationship between morale and productivity where the experimentally manipulated variable, closeness of supervision, is the logical choice of an independent variable for causal implication if any is to be chosen. Two other interesting studies also show an inverse relationship. Goode and Fowler found negative correlations between morale and productivity of unskilled workers on an assembly line.[9] On the other hand, in one of the relatively few studies that deal with the morale and productivity of people other than workers or clerks, Weschler, Kahane, and Tannenbaum compared two divisions in an industrial research laboratory, one permissively and one restrictively led.[10] Although the permissively led group had much higher morale and made substantially higher estimates of their own productivity than did the restrictively led division, superiors rated the latter more highly than their own estimates and more highly than the former. The authors concluded that the director of the permissively led division "utilized the services of a high morale group and of satisfied people in the performance of tasks which his superiors did not consider of highest importance to the laboratory."[11]

It is not our intent here to resist the efforts of those who strive to make organizations better places to work. We wish merely to point out that the evidence relating to leadership style and the beneficial effects of morale is mixed.

Participation—Some Evidence

To return more specifically to participation per se, the evidence does not bear out Becker and Green's implication that, as long as "participants participate" the effects will be beneficial.[12] Indeed, recent studies have shown that the effects of participation are heavily conditioned by personality and environmental factors.

It is interesting to note that the study of French, Israel, and Ås,[13] which was intended to provide, in a different cultural setting, corroboration of the findings of Coch and French,[14] pro-

Company, 1961). Before taking this evidence too seriously, however, the reader should be cautioned that it is not clear that all accounts are uniformly unbiased. For further discussion on this point see H. J. Leavitt's review of Likert's book in *Management Science,* X, No. 1 (September, 1963), 162–64.

9 W. J. Goode and I. Fowler, "Incentive Factors in a Low Morale Plant," *American Sociological Review* (1949), pp. 618–24.

10 I. R. Weschler, M. Kahane, and R. Tannenbaum, "Job Satisfaction, Productivity and Morale," *Occupational Psychology.* XXVI (1952), 1–14.

11 *Ibid.,* p. 6.

12 One can, of course, dismiss all evidence that does not support the participation hypothesis on the basis that in the case studied it was not *really* participation but "pseudo-participation." That this conclusion is generally arrived at ex post appears to be no deterrent [see C. Argyris, *The Impact of Budgets on People* (New York: The Controllership Foundation, 1958)].

13 J. R. P. French, Jr., J. Israel, and D. Ås, "An Experiment on Participation in a Norwegian Factory," *Human Relations,* XIII (1960), 1–13. Becker and Green borrow a definition from this article (n. 11, p. 394) but are unaware of, or do not care to present, the implications of their data.

14 L. Coch and J. R. P. French, Jr., "Overcoming Resistance to Change," *Human Relations* I (1948), 512–32. Since Becker and Green devote a column to this study (pp. 395–96) we shall deal with it only in passing. The reader should be cautioned, however, as to the value judgments present even in their qualifying remarks, as epitomized by the paragraph on p. 396: "Based only on this study one cannot decide if participation directly increased incentive to produce, as measured by subsequent productivity, or only improved morale, which in turn led to increased motivation. This is a point worth considering since morale is not perfectly correlated with productivity."

vided quite different results. Participation apparently improved *morale,* but *productivity* was unaffected. Although the authors indicate that the long-run effect of improved morale should be improved productivity, they present no evidence to this effect.[15] In short, the attempt to repeat the earlier study in a different organization in a different culture produced quite different results. Whether one cares to view the second study as indicative of mitigation of beneficial participation effects through national cultural translation, or merely through transfer to a different organizational culture,[16] the nonuniversality of the participation hypothesis of improved productivity should be clear.

In an attempt to isolate some of the variables conditioning the effects of participation, Vroom studied the relationship of participation to productivity of shipping supervisors.[17] While his results are drawn from survey data, the conditioning variables were obtained a priori from questionnaire information. He found that, where employees viewed participation as *legitimate,* productivity was higher under participative supervision, but, where it was viewed as not legitimate (e.g., evidence of "softness," inability to make decisions), observed productivity was lower. Vroom makes a convincing case for the persistence of such personality differences in the presence of quite dissimilar leadership styles. In light of this evidence we cannot conclude that participation will work for "all of the people all of the time" even if one were to alter situational variables so as to be more compatible with participation.

More recent evidence from a field experiment conducted by French, Kay, and Meyer is directly relevant to questions of participative budgeting, inasmuch as the amount of participation of goal planning sessions was explicitly manipulated.[18] Results indicated that the differences in goal attainment between participatively set and nonparticipatively set goals were neither significant nor necessarily in the hypothesized direction (i.e., participation would improve goal attainment). Subsequent analysis of the same data by Kay revealed that those supervisors whom the manipulation had left unchanged from their previous perceived participation in goal setting (e.g., perceived low participation in normal working relationship and were in low participation experimental treatment) had significantly higher goal attainments than those who had previously perceived one level of participation and for whom the manipulation had changed (in either direction) the level of participation.[19] Thus in the only study to date which explicitly deals with the amount of participation as the independent variable in a budget-related situation, the only significant results relating to participation and performance are ex post and specifically oppose the hypothesis that a change *to* participative goal setting will improve performance.

Thus it can be seen that, in their

[15] For discussion of a similar assertion, cf. H. J. Leavitt, *op. cit.* (footnote 8). Unfortunately, the reader must be cautioned, in general, to examine the data rather than conclusions or summaries of results in this literature.

[16] It is not apparent that the original study was corroborated in any other domestic organization before "cross-cultural" corroboration was attempted.

[17] V. H. Vroom, *Some Personality Determinants of the Effects of Participation* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

[18] J. R. P. French, Jr., E. Kay, and H. H. Meyer, *A Study of Threat and Participation in a Performance Appraisal Situation* (New York: General Electric Co., 1962).

[19] Communicated to the author in private correspondence.

reliance on the "use" of participation, the attempt to enhance morale and hence productivity, and the consequent stress on "democratic" organization, Becker and Green are forced into a position antithetical to both their original fundamental points and much of the extant evidence.

Aspiration Levels and Performance

One might say that the character of existing psychological evidence is at the root of the difficulty Becker and Green face in their attempt to extrapolate directly to problems in an industrial organization. This difficulty is particularly poignant in their discussion of aspiration levels and performance.

In general, phychological research dealing with goals has been directed toward the description and explanation of the goal formation process. This research has dealt almost exclusively with the influence *on* aspiration levels of previous performance, success or failure in attainment of previous aspiration levels, other psychological variables, and cultural phenomena—for example, social norms. The emphasis has been placed on the process of goal formation and not on performance resulting from the formation of a particular goal. Explicit investigation of performance as a dependent variable has been rare; in psychological research the aspiration level has, with few exceptions, been treated as the dependent variable.[20] The study of performance as a function of an aspiration level that is in turn a function of a goal (which is, at least in part, determined by an external source) has not, apparently, been of interest to psychologists.

Becker and Green seem quite concerned about an experiment I performd a few years ago in which I attempted to depart from the usual arrangement of dependent and independent variables in psychological research. For the reasons cited above it is quite reasonable that Becker and Green may have misinterpreted my experimental work.[21] After discussing the attributes of several different kinds of aspiration level statements, they conclude: "Since level of aspiration is defined as the goal one explicitly undertakes to reach rather than the goal one hopes to achieve, it seems clear that Stedry's conclusions are based on an inaccurate measure of his major variable" (p. 398). Inasmuch as the study in question focused on budgeting control problems, performance was chosen as the dependent variable. The experimental treatments (in a 4×3 factorial design) involved (1) the variation of the difficulty of goals presented by the experimenter and (2) variation of the presence or absence of the solicitation of a hope statement and the timing of the statement—before or after the presentation of the experimenter's goal. The observed experimental performance results showed significant differences between treatments in both variations and significant interactions were noted as well.[22] The inferences made for budgeting were drawn from these results. Recognizing that these results per se would not be of primary interest to psychologists, aggregated data on the results of the aspiration level questionnaires were also pre-

[20] Becker and Green cite two of them: J. A. Bayton, "Interrelations between Levels of Aspiration, Performance and Estimates of Past Performance," *Journal of Experimental Psychology,* XXXIII (1943), 1; and S. Siegel and L. E. Fouraker, *Bargaining and Group Decision Making: Experiments in Bilateral Monopoly* (New York: McGraw-Hill Book Company, 1960).

[21] A. C. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

[22] For detailed results, see *ibid.*

sented. The reader may verify the tentativeness with which inferences from these auxiliary data were drawn.

I would like to pause a moment, however, to explain that the unanimity among psychologists on the wording of aspiration level statements implied by Becker and Green simply does not exist. Even if we confine ourselves to those references which they cite, Festinger defines two measures of aspiration level based upon questions involving "like to get" and "expect to get."[23] Diggory uses both "hope" statements and "expect" statements as *measures of aspiration level.*[24] Neither author explicitly implies a preference for "expect." Intuitively, at least, "expect" implies prediction and either "try" or "hope" would seem closer to the "explicitly undertakes to reach" concept proposed by Frank.[25] Of particular relevance to a discussion of an appropriate measure of aspiration level in dealing with performance are some misgivings about "expect" mentioned in a footnote by Bayton:

> Some investigators have questioned the key term used in the instructions given in those level of aspiration experiments which follow Frank's procedure. Irwin and Mintzer... have indicated the inconsistency which exists among previous workers, since some asked their subjects to state what they expected to make, one asked what his subjects intended to make, another asked, "What will you make?" and still another used "What will you try to make?" The present experiment employs the most consistently used term—"expect." Irwin in personal communication with the writer has raised the question of whether instructions asking the subjects to state what they expect to make have the same meaning as those requiring them to state what they are trying to make, and claims that if the incentive value of the level of aspiration is being studied, the latter instructions should be used. Since Irwin and Mintzer demonstrate a difference in aspiration statement when their instructions asked for predictions as against hopes, support is given Irwin's criticism. However, the present experiment is designed to test the incentive value of the level of aspiration as it is generally conceived, and it therefore uses the term most consistently found in the instructions of other investigators.[26]

In dealing with budgeting research, it would seem a mistake to ignore the possibility of more than one kind of aspiration level being formed. While a prediction or expectation (probably closest to a forecast in budgeting parlance) might be formed, an intent to attain a budgeted performance which differs from an expected (median or mean value) performance might be held. Indeed, if the budget were equal to the expectation which would exist in the absence of the budget figure its purpose would be difficult to detect.[27] The question of a simultaneous existence of several levels of aspiration is not new. Gardner, for example, asks:

> Might not an individual in a task such as dart throwing entertain, at one and the same time, a wild hope that he will make a perfect hit and a more prudent hope that he will at least hit the target, with perhaps an additional, self-conscious hope that he

[23] L. Festinger, "A Theoretical Interpretation of Shifts in Level of Aspiration," *Psychological Review,* XLIX (1942), 235–50.

[24] J. C. Diggory, "Responses to Experimentally Introduced Failure," *American Journal of Psychology,* LXII (1949), 48–61.

[25] J. D. Frank, "Individual Differences in Certain Aspects of the Level of Aspiration," *American Journal of Psychology,* XLVII (1935), 119–28.

[26] Bayton, *op. cit.,* p. 3. It is unclear how, inasmuch as this article is cited by Becker and Green, a "term most consistently found" but obviously questioned as a measure could have been taken by them as irrevocably correct or accurate.

[27] An extended discussion of this point may be found in Stedry, *op. cit.,* Chaps. i and ii.

will not appear too awkward in the eyes of the experimenter? In other words, is there not considerable likelihood that an individual's aims on a given trial are manifold, fluctuant, ephemeral, and differing qualitatively as well as quantitatively, with those aims which involve a specific score often giving way to aims which cannot possibly be described in terms of score values?[28]

One can readily perceive the relevance of Gardner's remarks to a budgeting situation in which the simultaneous presence of a desire to do really well, a desire to "make the budget," and a desire not to fall below some minimally acceptable level exists. The face validity of an expectation measure of a level of intended achievement (however often used by psychologists) is not apparent; the use of a single measure—prediction—in budgetary control research seems unnecessarily limiting, if not unsound.

Conclusion

This discussion should not imply that the use of psychological constructs is undesirable in budgeting research. On the contrary, in the opinion of this writer not only psychological research but research emanating from all of the social sciences should be used where applicable—but should be used well.

Interdisciplinary work in its application of theory and findings to new contexts demands meticulous interpretation of previous studies lest potential for contribution be lost. A case in point is Becker and Green's treatment of the well-known study of Schachter and others, the conclusion of which reads in part: "In summary, the data indicate no necessary relationship between cohesiveness and high productivity. . . . Whether or not highly cohesive groups are more likely to develop standards of high production rather than low production is a separate question, but evidence from industrial studies. . . e.g., the slow down, indicates that this is not the case."[29]

Becker and Green, however, derive this summary: "Since participation affects morale (cohesiveness) and productivity, but cohesiveness without participation affects production, the most likely conclusion is that cohesiveness is dependent on participation but that changes in productivity are more directly related to cohesiveness" (p. 396).

The intermeshing of disciplines is valuable, regardless of the researcher's original training, if evidence is impartially selected and weighed in relation to both its original and new application. Further, the infusion of other disciplines is valuable only if the result creates new areas of potential exploration rather than fading indistinguishably into the current budgeting literature.

[28] J. W. Gardner, "The Use of the Term 'Level of Aspiration,'" *Psychological Review,* XLVII (1940), 65. This quotation appears in full in Bayton (*op. cit.*), cited by Becker and Green if selectively paraphrased by them (p. 399).

[29] S. Schachter, N. Ellertson, Dorothy McBride, and Doris Gregory, "An Experimental Study of Cohesiveness and Productivity," *Human Relations,* IV (1951), 229–38.

BUDGETING AND EMPLOYEE BEHAVIOR: A REJOINDER TO A "REPLY"

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A brief restatement of Becker and Green's position is presented in answer to Stedry's "reply."

In our "Budgeting and Employee Behavior" we made two statements: (1) a reiteration of McGregor's fundamental reservation that "participation is not a panacea"; and (2) the assertion that "participation is *not* a single-value variable but rather a concept encompassing several explicit variables." Stedry agrees with the substance of these statements and attributes to us the notion that these statements are the "fundamentals" of our argument. He states: "It is not clear how, reasoning from these fundamentals, they arrive at a set of conclusions."[1] Stedry not only is unclear about the reasoning which leads to our conclusions, he also is unclear about what constitutes the fundamentals of an argument.

We stated an interest in exploring "the *belief* that increased participation can lead to better morale and increased initiative."[2] Having noted that such belief is inconsistent with the literature (we, too, knew about the results of the French, Israel, and Ås study), we stated our reservation and hypothesized that participation was not a panacea because it was not a simple variable but a complex of variables summarized under at least two concepts, process and content. An understanding of these concepts, we felt, would allow us to specify the conditions under which participation could produce beneficial results.

The fundamentals of our position and the reasoning which led us to our conclusions are as follows:

Given that participation is an interaction through which individuals become involved in managerial decisions which affect them—the essence of "process" and "content":

1. *If* greater interaction leads to greater group cohesiveness, and *if* group cohesiveness and induction to produce at either a higher or lower rate are positively correlated,[3] *then* the process of

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1 "Budgeting and Employee Behavior: A Reply," *The Journal of Business* (January, 1964), p. 195.

2 "Budgeting and Employee Behavior," *The Journal of Business* (October, 1962), p. 394.

3 In his conclusion Stedry compares a statement made by Schachter *et al.* with one we made. His citation from Schachter *et al.* was: "In summary, the data indicate no necessary relationship between cohesiveness and high productivity...whether or not highly cohesive groups are more likely to develop standards of high production is a separate question," etc. We would like to fill in the ellipsis: "Group members will accept induction either to increase or decrease production." Schachter *et al.* also state: "The relations between cohesiveness and productivity are as follows: Communications calling for increased production result in no significant differences between the high and low cohesive groups. There are differences, however, when the notes urge a reduction in production. In this "slowdown"

participation can be used to induce either higher or lower production.

2. *If* participation at an upper level generates positive attitudes on the part of the participating supervisors, *then* individual supervisors (each being a member of a cohesive subgroup) will attempt to induce those group and individual aspirations at the subgroup level which lead to higher rather than lower production.
3. *If* aspirations for high levels of performance are induced, *then* higher levels of performance will ensue,
4. *If* expectations of reward or punishment associated with the achieved level of performance are validated on the basis of knowledge of that achievement, *then* communication of results can affect subsequent levels of aspiration and subsequent performance.
5. *Therefore,* as we implied in our first paper, a successful participation budget increases group cohesiveness and induces positive attitudes, and
6. *Therefore,* as we made explicit in our first paper, a successful participation budget does two things: (1) It induces proper motivation and acceptance of specific goals, and (2) it validates expectations to associating reward or punishment with performance. These lead to new aspirations and motivations that set the state for the next participation budget,[4] the very conclusion to which Stedry objects. Let us examine each of the *"if-then"* statements and evaluate Stedry's remarks in terms of their relevance to the issues.

The first section of Stedry's review of the "relevant" (his adjective) literature, leadership style, and productivity is concerned primarily with worker reaction to foreman behavior and attitude. This section of the literature review is irrelevant to our intended argument for two reasons: (1) it pertains to none of the "if-then" clauses, and (2) our argument was restricted to supervisory personnel above first line to minimize member and reference group differences. We tried to make this restriction clear in discussing the effects of knowledge of results when we stated," "If he is not informed of the results of the comparison, he cannot know whether his striving for a particular level was worthwhile or not. Nor can he, in turn, pass on the word to *his subordinates* in whom he induced specific levels of aspiration."[5] We also stated, "The participating *supervisors* bring to the new participation situation. . . ."[6] However, we are vulnerable on the clarity of this distinction and our failure to include first line supervisors.

In the second section, Stedry is concerned with the relation between morale and productivity. He cites literature to support the conclusion that morale and productivity are not perfectly correlated. He is, of course, absolutely correct. In our argument we demonstrated that cohesiveness was almost synonymous with the usual use of the term "morale." One of our "if-then" clauses is that high cohesiveness (high morale) leads either to higher or lower production. Thus we have no disagreement with this section of Stedry's review.

In the third segment Stedry discusses participation and our implication that as long as participants participate the effects will be beneficial. He cites the French, Israel, and Ås study and then comes up with the conclusion that "the

condition, subjects in high cohesive groups decrease continuously from induction period to induction period. Scores for both periods are significantly below the base line level of production at better than the 1 per cent level of confidence" (S. Schachter, N. Ellertson, D. McBride, and D. Gregory, "An Experimental Study of Cohesiveness and Productivity," *Human Relations,* No. 4 [1951], 229–38).

[4] Becker and Green, *op. cit.,* p. 401.

[5] *Ibid.,* p. 399.

[6] *Ibid.,* p. 400.

nonuniversality of the participation hypothesis of improved productivity should be clear."[7] Is this not merely a nonalliterative restatement of the phrase, "Participation is not a panacea"? In this section Stedry also cites evidence that those who view participation as legitimate increase their productivity under participative supervision and decrease it where it was not viewed as legitimate. This is relevant to our "if-then" clause that only when the content of participation produces positive attitudes will higher rather than lower levels of aspiration be induced, followed, in turn, by higher rather than lower production.

The view that participation is not a legitimate managerial tool, that it is used only for manipulative purposes, would preclude the adoption of positive attitudes subsequent to participation, thus increasing the likelihood that lower rather than higher levels of aspiration would be adopted. It cannot be guaranteed that those who view it as legitimate will automatically adopt positive attitudes. Should personality clashes or other unfavorable (to the group) content result from participation, few positive attitudes will develop and group cohesiveness will remain low. This part of Stedry's review is not contradictory to our argument and is complementary to one of the "if-then" clauses.

The fourth and final segment is devoted to aspiration levels and performance. We assumed that higher levels of aspiration lead to higher goal attainment (higher productivity) and cited two studies in support of the assertion. We also noted, in passing, that we were not citing Stedry in support of this assumption even though he stated,

> The group of high budget subjects who received their budgets prior to setting their aspiration levels performed better than any other group, whereas the "high" budget group who set their aspirations before receiving the budget were the lowest performance of any group.
>
> An hypothesis which might satisfactorily explain this phenomenon is as follows: The high performing group formed its aspirations with the high budget levels in mind, while the low performing group rejected the high budget after forming aspirations with relation to their last performance.[8]

In effect, he hypothesizes that the low performers rejected a higher level of aspiration; otherwise they might have performed at a higher level. This conjecture was necessary because the data were equivocal regarding this relationship. We also question the efficacy of allowing subjects to select a goal; then, after telling them their goal should be higher than the one selected, ask what they *hope* to achieve and take that response as the goal for which they are striving—the one which should bring feelings of success if reached and feelings of failure if not reached. This section of his review relates to our questioning the method he used in measuring level of aspiration but is not relevant to the central argument or to any of the "if-then" clauses.

To sum up, where Stedry has not presented irrelevancies, he twice has agreed with or cited data in support of our arguments. Nor has he offered an alternative to our conclusions. We might better have entitled this "A Rejoinder to a 'Nonreply.' "

[7] Stedry, p. 198.

[8] A. C. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960), pp. 89–90.

DYSFUNCTIONAL CONSEQUENCES OF PERFORMANCE MEASUREMENTS

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Although quantitative measures of performance are undoubtedly useful, their behavioral side effects should be carefully considered to gauge their net benefits. The consequences of using single, multiple, and composite criteria for performance measurement are examined. Each of these three types of criteria can lead to undesirable consequences for overall organizational performance. Further research is required if we are to understand the motivational potentials of various performance measurement systems.

There is today a strong tendency to state numerically as many as possible of the variables with which management must deal. The mounting interest in and application of tools, such as operations research, linear programming, and statistical decision making, all of which require quantifiable variables, foster the idea that if progress toward goals can be measured, efforts and resources can be more rationally managed. This has led to the development of quantitative performance measurements for all levels within organizations, up to and including measurements of the performance of a division manager with profit responsibility in a decentralized company. Measurements at lower levels in the organization may be in terms of amount of work, quality of work, time required, and so on.

Quantitative measures of performance are tools, and are undoubtedly useful. But research indicates that indiscriminate use and undue confidence and reliance in them result from insufficient knowledge of the full effects and consequences. Judicious use of a tool requires awareness of possible side effects and reactions. Otherwise, indiscriminate use may result in side effects and reactions outweighing the benefits, as was the case when penicillin was first hailed as a wonder drug. The cure is sometimes worse than the disease.

It seems worthwhile to review the current scattered knowledge of the dysfunctional consequences resulting from the imposition of a system of performance measurements. For the purpose of analyzing the impact of performance measurements upon job performance, we can consider separately single, multiple, and composite criteria. Single criteria occur when only one quantity is measured and observed, such as total output or profit. Multiple criteria occur when several quantities are measured simultaneously, such as output, quality, cost, safety, waste, and so forth. Composite criteria occur when the separate quantities are weighted in some fashion and then added or averaged.

Single Criteria

A single criterion of performance was in use in a public employment agency studied by Peter M. Blau.[1] The

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[1] Peter M. Blau, *The Dynamics of Bureaucracy* (Chicago: The University of Chicago Press, 1955).

agency's responsibility was "to serve workers seeking employment and employers seeking workers." Employment interviewers were appraised by the number of interviews they conducted. Thus the interviewer was motivated to complete as many interviews as he could, but not to spend adequate time in locating jobs for the clients. The organization's goal of placing clients in jobs was not given primary consideration because the measurement device applied to only one aspect of the activity.

Blau reports another case in a federal law enforcement agency which investigated business establishments. Here he found that work schedules were distorted by the imposition of a quota of eight cases per month for each investigator. Toward the end of the month an investigator who found himself short of the eight cases would pick easy, fast cases to finish that month and save the lengthier cases till the following month. Priority of the cases for investigation was based on length of the case rather than urgency, as standards of impartiality would require. This is one of many instances in which the existence of an "accounting period" adversely affects the overall goal accomplishment of the organization.

Chris Argyris also reports this tendency to use easy jobs as fillers toward the end of a period in order to meet a quota.[2] In this case, a factory supervisor reported that they "feed the machines all the easy orders" toward the end of the month, rather than finish them in the sequence in which they were received. Such a practice may lead to undue delay of the delivery of some customers' orders, perhaps the most profitable orders.

David Granick's study of Soviet management reveals how the attention and glory that accrue to a plant manager when he can set a new monthly production record in one month lead to the neglect of repairs and maintenance, so that in ensuing months there will be a distinct drop in production.[3] Similarly, the output of an entire plant may be allowed to fall off in order to create conditions under which one worker can make a production record, when the importance of such a record is considered greater than overall plant production.

Joseph S. Berliner's report on Soviet business administration points out sharply how the accounting period has an adverse effect upon management decisions.[4] The use of monthly production quotas causes "storming" at the end of the month to reach the quota. Repairs and maintenance are postponed until the following month, so that production lags in the early part of the month, and storming must again be resorted to in the following month. This has impact upon the rate of production for suppliers and customers who are forced into a fluctuating rate of operations with its attendant losses and wastes.

Standard costs as a criterion of performance is a frequent source of dissatisfaction in manufacturing plants.[5] The "lumpiness" of indirect charges that are allocated to the plants or divisions (indirect charges being unequal from month to month), variations in quality and cost of raw materials, or

[2] Chris Argyris, *The Impact of Budgets on People* (New York: The Controllership Foundation, 1952).

[3] David Granick, *Management of the Industrial Firm in the U.S.S.R.* (New York: Columbia University Press, 1954).

[4] Joseph S. Berliner, "A Problem in Soviet Business Management," *Administrative Science Quarterly,* 1 (1956), 86–101.

[5] H. A. Simon, H. Guetzkow, G. Kozmetsky, G. Tyndall, *Centralization vs. Decentralizitaon in Organizing the Controller's Department* (New York: The Controllership Foundation, 1954).

other factors beyond the control of the operating manager, coupled with inaccuracies and errors in the apportionment of indirect charges, cause distrust of the standards. A typical reaction of operating executives in such cases seems to be to seek explanations and justifications. Consequently, considerable time and energy is expended in discussion and debate about the correctness of charges. Only "wooden money" savings accrue when charges are shifted to other accounts, and there is no increase in company profits. It should be pointed out, however, that having charges applied to the proper departments may have the advantage of more correctly directing attention to problem areas.

Granick discusses two measures of the success of the Soviet firm which have been considered and rejected as overall measures by Soviet industrial leaders and economists.[6] The first, cost reduction per unit of product, is considered inadequate because it does not provide a basis for evaluating new products. Further, variations in amount of production affect the cost reduction index because of the finer division of overhead costs, quality changes, and assortment. The second overall measure of a firm's performance, profitability, has been rejected as the basic criterion on the grounds that it is affected in the short run by factors outside the control of management, such as shortages of supplies. Profitability as a measure of success led to a reduction in experimental work and deemphasized the importance of production quantity, quality, and assortment. Neither cost reduction nor profitability was acceptable alone; each was only a partial index. The Soviets had concluded by 1940 that no single measure of success of a firm is adequate in itself and that there is no substitute for genuine analysis of all the elements entering into a firm's work.

Difficulties with single criteria have been observed in operations research, where one of the principal sources of difficulty is considered to be the choice of proper criteria for performance measurement.[7] The difficulty of translating the several alternatives in their full effect upon the organization's goal forces the operations researcher to settle for a criterion more manageable than profit maximization, but less appropriate. The efficiency of a subgroup of the organization may be improved in terms of some plausible test, yet the organization's efficiency in terms of its major goal may be decreased.

In all the studies mentioned above, the inadequacy of a single measure of performance is evident. Whether this is a measure of an employee at the work level or a measure of management, attention is directed away from the overall goal. The existence of a measure of performance motivates individuals to effort, but the effort may be wasted, as in seeking "wooden money" savings or may be detrimental to the organization's goal, as in rushing through interviews, delaying repairs, and rejecting profitable opportunities.

Multiple Measurements

Recognition of the inadequacies of a single measure of success or performance leads organizations to develop several criteria. It is felt then that all aspects of the job will receive adequate attention and emphasis, so that efforts of individuals will not be distorted.

[6] Granick, *op. cit.*

[7] Charles Hitch and Roland McKean, "Suboptimization in Operations Problems," in *Operations Research for Management*, eds. J. F. McCloskey and Flora F. Trefethen (Baltimore: Johns Hopkins Press, 1954).

A realization in the employment office studied by Blau that job referrals and placements were also important led eventually to their inclusion in measuring the performance of the interviewers.[8] Merely counting the number of referrals and placements had led to wholesale indiscriminate referrals, which did not accomplish the employment agency's screening function. Therefore, to stress the qualitative aspects of the interviewer's job, several ratios (of referrals to interviews, placements to interviews, and placements to referrals) were devised. Altogether there were eight quantities that were counted or calculated for each interviewer. This increase in quantity and complexity of performance measurements was felt necessary to give emphasis to all aspects of the interviewer's job.

Granick relates that no single criterion was universally adopted in appraising Soviet management.[9] Some managers were acclaimed for satisfying production quotas while violating labor laws. Others were removed from office for violating quality and assortment plans while fulfilling production quotas. Apparently there is a ranking of importance of these multiple criteria. In a typical interfirm competition, the judges were provided with a long list of indexes. These included production of finished goods in the planned assortment, an even flow of production as between different ten-day periods and as between months, planned mastery of new types of products, improvement in product quality and reduction in waste, economy of materials through improved design, and changing of technological processes, fulfillment of labor productivity tasks, and lowering of unit cost, keeping within the established wage fund, and increase in the number of worker suggestions for improvements in work methods and conditions and their adoption into operation. But no indication of how these indexes should be weighted was given. The pre-eminence of such indexes as quantity, quality, assortment of production, and remaining within the firm's allotment of materials and fuels, brought some order into the otherwise chaotic picture. The presence of "campaigns" and "priorities" stressing one or more factors also has aided Soviet management in deciding which elements of its work are at the moment most important.

Without a single overall composite measure of success, however, there is no way of determining whether the temporarily increased effort on the "campaign" criteria of the month represents new effort or merely effort shifted from other criteria. And the intangibility of some of these indexes makes it impossible to judge whether there has been decreased effort on other aspects. Hence even in a campaign period the relative emphases may become so unbalanced as to mitigate or defeat the purpose of the campaign.

The Soviet manager is working then under several measurements, and the relative influence or emphasis attached to any one measurement varies from firm to firm and from month to month. Profits and production are used, among other measurements, and these two may lead to contradictory managerial decisions. Granick hypothesizes that some managers have refused complicated orders that were difficult to produce because it would mean failure to produce the planned quantities. Acceptance of these orders would have been very profitable, but of the two criteria, production quantity took precedence.

Numerous American writers in the

[8] Blau, *op. cit.*

[9] Granick, *op. cit.*

field of management have stressed the importance of multiple criteria in evaluating performance of management. Peter Drucker, for example, lists market standing, innovation, productivity, physical and financial resources, profitability, manager performance and development, worker performance and attitude, and public responsibility.[10] This list includes many of the same items as the list used by Soviet management.

The consensus at a round-table discussion of business and professional men[11] was that although return on investment is important, additional criteria are essential for an adequate appraisal of operating departments. These other criteria are fairly well summed up in Drucker's list above.

Thus we see that the need for multiple criteria is recognized and that they are employed at different levels of the organization—lower levels as in the employment agency, higher levels as considered by Granick and Drucker. At all levels these multiple measurements or criteria are intended to focus attention on the many facets of a particular job.

The use of multiple criteria assumes that the individual will commit his or the organization's efforts, attention, and resources in greater measure to those activities which promise to contribute the greatest improvement to overall performance. There must then exist a theoretical condition under which an additional unit of effort or resources would yield equally desirable results in overall performance, whether applied to production, quality, research, safety, public relations, or any of the other suggested areas. This would be the condition of "balanced stress on objectives" to which Drucker refers.

Without a single overall composite measure of performance, the individual is forced to rely upon his judgment as to whether increased effort on one criterion improves overall performance, or whether there may be a reduction in performance on some other criterion which will outweigh the increase in the first. This is quite possible, for in any immediate situation many of these objectives may be contradictory to each other.

Composites

To adequately balance the stress on the contradictory objectives or criteria by which performance of a particular individual or organization is appraised, there must be an implied or explicit weighting of these criteria. When such a weighting system is available, it is an easy task to combine the measures of the various subgoals into a composite score for overall performance.

Such a composite is used by the American Institute of Management in evaluating and ranking the managements of corporations, hospitals, and other organizations.[12] These ratings are accomplished by attaching a numerical grade to each of several criteria, such as economic function, corporate structure, production efficiency, and the like. Each criterion has an optimum rating, and the score on each for any particular organization is added to obtain a total score. Although there may be disagreement on the validity of the weighting system employed, the rating given on any particular category, the categories themselves, or the methods of estimating scores in the A.I.M. manage-

[10] Peter M. Drucker, *The Practice of Management* (New York: Harper & Row, Publishers, 1954).

[11] Wiliam H. Newman and James P. Logan, *Management of Expanding Enterprises* (New York: Columbia University Press, 1955).

[12] *Manual of Excellent Managements* (New York, 1955).

ment audit, this system is an example of the type of overall performance measurement which might be developed. Were such a system of ratings employed by an organization and found acceptable by management, it presumably would serve as a guide to obtaining a balanced stress on objectives.

A composite measure of performance was employed in Air Force wings as reported by K. C. Wagner.[13] A complex rating scheme covering a wide range of activities was used. When the organizations were put under pressure to raise their composite score without proportionate increases in the organization's means of achieving them, there were observable unanticipated consequences in the squadrons. Under a system of multiple criteria, pressure to increase performance on one criterion might be relieved by a slackening of effort toward other criteria. But with a composite criterion this does not seem as likely to occur. In Wagner's report individuals were subjected to tension, role and value conflicts, and reduced morale; air crews suffered from intercrew antagonism, apathy, and reduced morale; organization and power structures underwent changes; communications distortions and blockages occurred; integration decreased; culture patterns changed, and norms were violated. Some of these consequences may be desirable, some undesirable. The net result, however, might easily be less effective overall performance.

These consequences were observable in a situation where goals were increased without a corresponding increase in means, which seems to be a common situation. Berliner refers to the "ratchet principle" wherein an increase in performance becomes the new standard, and the standard is thus continually raised. Recognition of the operation of the "ratchet principle" by workers was documented by F. J. Roethlisberger and William J. Dickson.[14] There was a tacit agreement among the workers not to exceed the quota, for fear that the job would then be rerated. Deliberate restriction of output is not an uncommon occurrence.

Although the experiences reported with the use of composite measures of performance are rather skimpy, there is still a clear indication that their use may have adverse consequences for the overall performance of the organization.

Conclusion

Quantitative performance measurements—whether single, multiple, or composite—are seen to have undesirable consequences for overall organizational performance. The complexity of large organizations requires better knowledge of organizational behavior for managers to make best use of the personnel available to them. Even where performance measures are instituted purely for purposes of information, they are probably interpreted as definitions of the important aspects of that job or activity and, hence, have important implications for the motivation of behavior. The motivational and behavioral consequences of performance measurements are inadequately understood. Further research in this area is necessary for a better understanding of how behavior may be oriented toward optimum accomplishment of the organization's goals.

[13] Kenneth C. Wagner, "Latent Functions of an Executive Control: A Sociological Analysis of a Social System under Stress," *Research Previews*, vol. 2 (Chapel Hill, N. C.: Institute for Research in Social Science, March, 1954), mimeo.

[14] F. J. Roethlisberger and William J. Dickson, *Management and the Worker* (Cambridge, Mass.: Harvard University Press, 1939).

Editorial Comment for Chapter 9

In the 1963 edition of the *Encyclopaedia Britannica,*[1] Carl Devine characterizes accounting as "a broad term that denotes certain theories, behavioral assumptions, measurement rules, and procedures for collecting and reporting useful information concerning the activities and objectives of an organization." Accounting theories, measurement rules, and procedures for collecting and reporting information have been extensively discussed in the literature. The behavioral assumptions underlying management information systems, however, have received relatively little attention until very recently. Designers of management information systems must consider not only the problem the user is trying to solve and the data required to solve it, but also how the manner and form of the data to be communicated may affect his behavior.[2] In this chapter the focus is on the impact of information systems on organizational performance, or the management control function of information systems. In Chapter 10 the emphasis will be on the role of information in the decision-making process.

That quantitative expressions of plans—principally budgets—influence the behavior of employees and managers seems to be a well-accepted proposition. Because behavior is shaped by other key variables, such as organization structure and group dynamics, leadership style, personality, and a large number of environmental factors, it is very difficult to isolate the impact of the budgetary process (particularly the effect of budget levels) on individual and group performance. Attempts to develop generic, all-purpose strategies for budgeting systems are not likely to succeed because the differential impact of other key variables is not given explicit attention. A more constructive approach would attempt to gain insight into preferred strategies for given configurations of the key variables. The resulting recommendations would state that, under an enumerated set of conditions, certain strategies demonstrate results superior to those of alternative strategies. Compelling research findings along these lines, however, are still forthcoming.

In the first reading, after reviewing the motivational advantages of decentralization, Benton expresses the opinion that responsibility accounting systems facilitate effective motivation. There is little doubt that responsibility accounting systems do motivate, but there is a serious question of whether they consistently motivate

[1] Volume 1, pp. 78–80.

[2] Jacob G. Birnberg and Raghu Nath, "Implications of Behavioral Science for Managerial Accounting," *The Accounting Review,* XLII (July, 1967), 468. This article provides an excellent overview of recent behavioral research efforts in management accounting.

in the best interests of the organization as a whole. There exists the danger that such a system may promote thinking that emphasizes the responsibility center—rather than the entire firm—as the dominant entity of interest for decision-making purposes. When this occurs the important relationships existing among responsibility centers are obscured or just simply ignored.

As the systems approach begins to permeate firms, new measurements and formats responsive to the systems notion should be initiated for tomorrow's responsibility accounting systems. Changes in their design will be greatly affected by changes evolving in organization structure.

Exception reporting is another aspect of responsibility accounting systems that requires careful reconsideration for its motivational possibilities. Because the emphasis in many, if not most, organizations is on unfavorable variances from standard (that is, mistakes and failures), the whole responsibility system is likely to be perceived as a threat to employees and managers. As McGregor points out, noncompliance, manifested by defensive, resistant, and agressive behavior, tends to appear in the presence of a perceived threat. He suggests that exception reporting "*could* be a positive motivational device if the emphasis were on recognition and reward for variances *above* standard."[3]

In considering the motivational aspects of budgets, a manager's desire for status, prestige, and power should not be overlooked. Williamson develops the notion of "expense preference" to link these managerial motives to measurements of economic activity.

> By expense preference I mean that managers do not have a neutral attitude toward all classes of expenses. Instead, some types of expenses have positive values attached to them: they are incurred not merely for their contributions to productivity (if any) but, in addition, for the manner in which they enhance the individual and collective objectives of managers. Conventional economic theory treats all expenses symmetrically: individuals are indifferent toward costs of all types. Expense preference replaces this attitude of indifference by positive tastes for certain classes of expenses. Asymmetry thus develops in the attitude toward costs.[4]

Positive preference is claimed for staff with such emoluments as expense accounts, executive services, private secretaries, and private airplanes. A useful question for organizations is whether and how their management control systems should distinguish the handling of positive expense preference items from other budgeted expenses. The answers are not clear, but the significance of the question for managerial morale and commitment, and, hence, organizational vitality, is apparent.

Continuing on the general theme of motivation and budgets, we find that Benston refers to important studies on the subject by Argyris,[5] Simon *et al.*,[6] and

[3] Douglas McGregor, "Do Management Control Systems Achieve Their Purpose?" *Management Review*, LVI (February, 1967), 11.

[4] Oliver E. Williamson, *The Economics of Discretionary Behavior: Managerial Objectives in a Theory of the Firm* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1964), p. 33.

[5] C. Argyris, *The Impact of Budget on People* (New York: The Controllership Foundation, 1952).

[6] H. A. Simon, H. Guetzkow, G. Kozmetsky, and G. Tyndall, *Centralization vs. Decen-*

Stedry.[7] A more recent study by Hofstede[8] should also be of considerable interest. It is based upon an extensive analysis of budget systems in six manufacturing plants in the Netherlands. Hoftstede views the budget system, with its own inputs and outputs, as part of the larger organizational systems. The outputs of the budget system are expressed in terms of contribution to the assumed goals of the organization—profitability in the interest of shareholders and well-being (job satisfaction) of employees of all ranks. Inputs are classified as either internal (capable of being influenced by management) or external. Internal inputs include setting budgetary standards, participation in the setting of standards by budgetees, technical and personal involvement by the controller's staff, and, most important, the behavior of the budgetee's superior. Of all the internal inputs, Hofstede found that superior-subordinate communications bear the most crucial relationships to outputs.

Since budget systems are open systems which interact with the environment outside the firm, Hofstede also considered the influence of external inputs. These include the type of people available as potential budgetees, that is, their personality, cultural background, age, length of service in a job, etc. Also included is the market a firm operates in, which largely determines the technology of its plant, the cost structure of its products, and the managerial climate of top management. Each of these inputs has an impact upon budget outputs.

The exchange between Becker and Green and Stedry will not be analyzed in detail here, since the authors have expressed their differences of opinion forcefully and lucidly. The three readings serve to emphasize the observation that attempts to articulate generic, all-purpose strategies for budgeting systems are not likely to be very compelling because the relationships among key variables influencing behavior are not uniform in different organizational settings. (Hofstede emphasizes this in his enumeration and analysis of internal and external budget inputs.) Consider for example, one of Stedry's criticisms of the Becker and Green paper. He contends that it is not reasonable for Becker and Green to examine the impact of participation budgets on behavior without discussing the relative merits of different leadership styles. Becker and Green, in turn, via a series of "if-then" statements specify the conditions (input variables) under which participation budgets can increase group cohesiveness, induce positive attitudes, and improve performance. In sum, the differences between Becker and Green and Stedry appear to result more from a lack of agreement concerning the input variables that should be considered than from a fundamental difference of budgeting philosophy.[9]

tralization in Organizing the Controller's Department (New York: The Controllership Foundation, 1954).

[7] Andrew C. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

[8] G. H. Hofstede, *The Game of Budget Control* (Assen, The Netherlands: Van Gorcum & Comp. N. V., 1967).

[9] To further illustrate this point, there appears to be even a lack of agreement concerning the level of personnel under consideration. Becker and Green state that their analysis was "restricted to supervisory personnel above first line." No such restriction was evident in the Stedry reading.

The choice of appropriate performance criteria is strategic in the design of effective motivational information systems. Possible dysfunctional consequences associated with single, multiple, and composite criteria described by Ridgway in the final reading should alert the information designer to proceed with great care in this area. In the previous chapter's discussion of decentralized control systems, we noted the potentially adverse consequences of a single criteria, such as book ROI. Recognizing that no single measurement can identify the totality of divisional and company objectives, some companies have introduced multiple considerations for decision guidance and subsequent performance review. General Electric, for example, to advance both its long-range and short-range objectives, has developed the widely known "key result areas" approach. These are the "key result areas" GE employs:

1. Profitability
2. Market position
3. Productivity
4. Product leadership
5. Personnel development
6. Employee attitudes
7. Public responsibility
8. Balance between short- and long-range goals

Even when used in conjunction with other criteria, a single criterion may well emerge as the dominant one. E. Kirby Warren observed this very point in connection with his recent empirical study of long-range planning.

> While the first key result area is profitability, the next six are oriented toward means of accomplishing longer-range goals. Then, in addition, the eighth key area clearly reinforces the importance of balance between long- and short-run goals. Yet, despite this emphasis, neither the president nor any of the men interviewed in this company could shed a great deal of light on how this balance was attained. *One found in this corporation the tremendous short-term pressures of profit-center evaluation as a constant threat to the remaining highly subjective, largely intangible, longer-range criteria.*[10]

As Ridgway observes, when multiple measurements are used, "the individual is forced to rely upon his judgment as to whether increased effort on one criterion improves overall performance, or whether there may be a reduction in performance on some other criterion which will outweigh the increase in the first." It seems reasonable to hypothesize that the individual's judgment is shaped by his conception of the hierarchy among the multiple criteria held by his superiors. For example, in the case described by Warren, we would hypothesize that top management ranked "profitability" first among the key result items.

Today, twelve years after publication of Ridgway's paper, his comment that

[10] E. Kirby Warren, *Long-Range Planning: The Executive Viewpoint* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1966), p. 66.

few experiences with composite measures of performance have been reported is still valid. Perhaps, the reluctance of organizations to adopt composite measures is well reasoned. After all, an explicit weighting of criteria implies that those who develop the weighting can express the preferred state of affairs for the organization. Furthermore, as environmental changes induce shifts in goal hierarchies, few composite measures would remain intact.

In brief, the choice among single, multiple, and composite measurements should be made with full knowledge of the risks involved in each. A single measurement obscures important goals or constraints and, hence, may be satisfactorily met while the overall organizational state of affairs is unacceptable. Multiple measurement systems enumerate goals, but judgments about trade-offs among conflicting goals must be made without appeal to a basic decision model, and thus may lead to inconsistent actions and/or to an undue emphasis on a selected goal or set of goals. Finally, the risk of the composite measurement system is that predetermined weightings necessarily suffer from rapid obsolescence and, of even more importance, may not be construed as relevant or equitable by the managers who are to be evaluated by the system.

SELECTED REFERENCES

See Selected References for Chapter 10.

10

Impact of Information on Decision Making

BEHAVIORAL ASSUMPTIONS OF MANAGEMENT ACCOUNTING

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Assumptions concerning organization goals, behavior of participants, behavior of management, and the role of management accounting are postulated both from the standpoint of the "traditional" management accounting view of the firm and that of modern organization theory. Well-conceived empirical research to measure the effectiveness of these alternative systems is urged. If the modern organization theory model proves to be a more realistic view of human behavior, then management accounting systems should be designed with greater awareness of and sensitivity to the complex social and psychological motivations and limitations of organization participants.

Accounting has been closely associated with the development of the modern business organization. Thus, we might expect accountants to show a strong interest in recent contributions to organization theory which increase our understanding of the business firm and how it functions. An examination of accounting literature, however, suggests that (despite the steadily increasing flow of accounting articles and texts incorporating the words *management* and *decisions* in their titles) accountants have been relatively unconcerned with current research in organization theory. Although the past few years have witnessed the beginnings of an effort to bridge this gap, much still remains to be done.[1] This paper attempts to

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[1] See, for example, Robert T. Golem-

TABLE 1

Behavioral Assumptions of "Traditional" Management Accounting Model of the Firm

Assumptions with respect to organization goals
1. The principal objective of business activity is profit maximization (economic theory).
2. This principal objective can be segmented into subgoals to be distributed throughout the organization (principles of management).
3. Goals are additive—what is good for the parts of the business is also good for the whole (principles of management).

Assumptions with respect to the behavior of participants
1. Organization participants are motivated primarily by economic forces (economic theory).
2. Work is essentially an unpleasant task which people will avoid whenever possible (economic theory).
3. Human beings are ordinarily inefficient and wasteful (scientific management).

Assumptions with respect to the behavior of management
1. The role of the business manager is to maximize the profits of the firm (economic theory).
2. In order to perform this role, management must control the tendencies of employees to be lazy, wasteful, and inefficient (scientific management).
3. The essence of management control is authority. The ultimate authority of management stems from its ability to affect the economic reward structure (scientific management).
4. There must be a balance between the authority a person has and his responsibility for performance (principles of management).

Assumptions with respect to the role of management accounting
1. The primary function of management accounting is to aid management in the process of profit maximization (scientific management).
2. The accounting system is a "goal-allocation" device which permits management to select its operating objectives and to divide and distribute them throughout the firm, i.e., assign responsibilities for performance. This is commonly referred to as "planning" (principles of management).
3. The accounting system is a control device which permits management to identify and correct undesirable performance (scientific management).
4. There is sufficient certainty, rationality, and knowledge within the system to permit an accurate comparison of responsibility for performance and the ultimate benefits and costs of that performance (principles of management).
5. The accounting system is "neutral" in its evaluations—personal bias is eliminated by the objectivity of the system (principles of management).

demonstrate that an understanding of behavioral theory is relevant to the development of management accounting theory and practice.

The discussion to be presented here may be summarized as follows:

1. The management accounting function is essentially a behavioral function, and the nature and scope of management accounting systems is materially influenced by the view of human behavior which is held by the accountants who design and operate these systems.
2. It is possible to identify a "traditional" management accounting model of the firm and to associate with this model certain fundamental assumptions about human behavior. These assumptions are presented in Table 1.
3. It is also possible to postulate behavioral assumptions based on modern organization theory and to relate them to the objectives of management accounting. A tentative set of such assumptions appears in Table 2 .

biewski, "Accountancy as a Function of Organization Theory," *The Accounting Review* (April, 1964), pp. 333–41; and John J. Willingham, "The Accounting Entity: A Conceptual Model," *The Accounting Review* (July, 1964), pp. 543–52.

TABLE 2

Some Behavioral Assumptions from Modern Organization Theory

Assumptions with respect to organization goals

1. Organizations are coalitions of individual participants. Strictly speaking, the organization itself, which is "mindless," cannot have goals—only the individuals can have goals.
2. Those objectives which are usually viewed as organizational goals are, in fact, the objectives of the dominant members of the coalition, subject to whatever constraints are imposed by the other participants and by the external environment of the organization.
3. Organization objectives tend to change in response to: (1) changes in the goals of the dominant participants, (2) changes in the relationships within the coalition, and (3) changes in the external environment of the organization.
4. In the modern complex business enterprise, there is no single universal organization goal such as profit maximization. To the extent that any truly overall objective might be identified, that objective is probably organization survival.
5. Facing a highly complex and uncertain world and equipped with only limited rationality, members of an organization tend to focus on "local" (i.e., individual and departmental) goals. These local goals are often in conflict with each other. In addition, there appears to be no valid basis for the assumption that they are homogeneous and thus additive—what is good for the parts of the organization is not necessarily good for the whole.

Assumptions with respect to the behavior of participants

1. Human behavior within an organization is essentially an adaptive, problem-solving, decision-making process.
2. Organization participants are motivated by a wide variety of psychological, social, and economic needs and drives. The relative strength of these diverse needs differs among individuals and within the same individual over time.
3. The decision of an individual to join an organization and the separate decision to contribute his productive efforts once a member are based on the individual's perception of the extent to which such action will further the achievement of his personal goals.
4. The efficiency and effectiveness of human behavior and decision making within organizations is constrained by: (1) the inability to concentrate on more than a few things at a time, (2) limited awareness of the environment, (3) limited knowledge of alternative courses of action and the consequences of such alternatives, (4) limited reasoning ability, and (5) incomplete and inconsistent preference systems. As a result of these limits on human rationality, individual and organizational behavior is usually directed at attempts to find satisfactory—rather than optimal—solutions.

Assumptions with respect to the behavior of management

1. The primary role of the business manager is to maintain a favorable balance between (1) the contributions required from the participants and (2) the inducement (i.e., perceived need satisfactions) which must be offered to secure these contributions.
2. The management role is essentially a decision-making process subject to the limitations on human rationality and cognitive ability. The manager must make decisions himself and must effectively influence the decision premises of others so that their decisions will be favorable for the organization.
3. The essence of management control is the willingness of other participants to *accept* the authority of management. This willingness appears to be a nonstable function of the inducement-contribution balance.
4. Repsonsibility is assigned from "above" and authority is accepted from "below." It is, therefore, meaningless to speak of the balance between responsibility and authority as if both of these were "given" to the manager.

TABLE 2

(Cont.)

Assumptions with respect to the role of accounting
1. The management accounting process is an information system whose major purposes are: (1) to provide the various levels of management with data which will facilitate the decision-making functions of planning and control and (2) to serve as a communications medium within the organization.
2. The effective use of budgets and other accounting control techniques requires an understanding of the interaction between these techniques and the motivations and aspiration levels of the individuals to be controlled.
3. The objectivity of the management accounting process is largely a myth. Accountants have wide areas of discretion in the selection, processing, and reporting of data.
4. In performing their function within an organization, accountants can be expected to be influenced by their own personal and departmental goals in the same way as other participants are influenced.

4. Research directed at testing the nature and validity of accounting assumptions with respect to human behavior in business organizations can be useful in evaluating and, perhaps, improving the effectiveness of management accounting systems.

Management Accounting as a Behavioral Process

The management of a business enterprise is faced with an environment—both internal and external to the firm—that is in a perpetual state of change. Not only is this environment constantly changing, but it is changing in many dimensions. These include physical changes (climate, availability of raw materials, etc.), technological changes (new products and processes, etc.), social changes (attitudes of employees, customers, competitors, etc.), and financial changes (asset composition, availability of funds, etc.).

An important characteristic of "good" management is the ability to evaluate past changes, to react to current changes, and to predict future changes. This is consistent with the view that management is essentially a decision-making process and the view that accounting is an information system which acts as an integral part of this decision-making process. It is inconceivable, however, that any workable information system could provide data relative to all, or even a substantial portion, of the changes occurring inside and outside of the organization. There are several reasons for this. Many changes—particularly those that occur in the external environment—are simply not available to the information system of the firm. These changes represent "external unknowns" in a world of uncertainty and limited knowledge. Further, a substantial number of changes that occur within the firm itself may not be perceived by the information system. Thus, there exist "internal" as well as "external" unknowns.

Even if accountants were aware of all the changes which are taking place—or if they could be made aware of them—they still would not be able to reflect them all within their information system. There must be a selection process, explicit or implicit, which permits the gathering and processing of only the most critical information and facilitates the screening out of all other data. In the first place, many items of information would cost more to

gather and process than the value of the benefits they would provide. Also, an excessive flow of data would "clog" the system and prevent the timely and efficient passage and evaluation of more important information.[2] Therefore, only a certain, very limited, set of data (i.e., observations about changes) can be selected for admission into the system. The essential point to be noted here is that decisions regarding what information is the most critical, how it should be processed, and who should receive it are almost always made by accountants. In addition, they are often directly involved, as participants, in the management decision-making process itself.

In carrying out these activities, accountants utilize a frame of reference that is, in effect, their view of the nature of the firm and its participants. The operation of their system requires them to be constantly abstracting a selected flow of information from the complex real world and using these selected data as the variables in their "model" of the firm. It seems clear that accountants exercise choice in the design of their systems and the selection of data for admission into them. It also seems clear that the entire management accounting process can be viewed from the standpoint of attempting to influence the behavior of others. It follows, therefore, that they must perform these functions with certain expectations with respect to the reactions of others to what they do. In other words, their model of the firm must involve some set of explicit or implicit assumptions about human behavior in organizations.

[2] This is the "capacity problem" discussed by Anton. See Hector R. Anton, *Some Aspects of Measurement and Accounting*, Working Paper No. 84 (Berkeley, Calif.: Center for Research in Management Science, University of California, 1963).

The "Traditional" View of Behavior

Once it has been demonstrated that the management accounting function does, by necessity, involve assumptions about behavior, the next task is to identify these assumptions. Our investigation is complicated by the fact that nowhere in the literature of accounting is there a formal statement of the behavioral assumptions of the management accounting model of the firm. It is necessary, therefore, to attempt to construct such a statement. We begin with the premise that present-day management accounting theory and practice is the product of three related conceptual forces, namely, industrial engineering technology, classical organization theory, and the economic "theory of the firm." An examination of the literature of management accounting suggests that accountants may have avoided the necessity of developing a behavioral model of their own by borrowing a set of assumptions from these other areas. If this thesis is valid, an appropriate point to begin the search for such assumptions is by an examination of the assumptions of these related models. Since much of the engineering view appears to be incorporated in the classical organization theory model,[3] it can probably be eliminated from this analysis without significant loss. Further, it appears that classical organization theory and economics do not represent two completely different views of human behavior, but rather that they share essentially a single view.

The following paragraphs will attempt to demonstrate that—with the

[3] One of the earliest, and perhaps the best, example of this consolidation can be found in the work of Taylor. See Frederick W. Taylor, *Scientific Management* (New York: Harper & Row, Publishers, 1911).

exception of the modern organization theory concepts of recent years—there has been a single view of human behavior in business organizations from the period of the industrial revolution to the present and that management accounting has adopted this view without significant modification or serious question as to its validity.

The Economic Theory of the Firm

It has been suggested that, from the beginnings of recorded history, the traditional determinants of human behavior in organizations have been either custom or physical force.[4] As long as this was the case, there was no real need for an organization theory or economic theory to explain how and why human beings worked together cooperatively to accomplish common goals. However, the changing structure of society, which accompanied—and to an extent caused—the industrial revolution, destroyed much of the force of these traditional determinants of behavior. The new entrepreneurial class of the eighteenth century sought not only a social philosophy to rationalize its actions, it also sought practical solutions to the immediate problems of motivating, coordinating, and controlling the members of its organizations. The second of these needs resulted in the development of the classical organization theories which will be discussed in the following section. The first need, i.e., the quest for a rationalization, ultimately led to the incorporation of the economic theory of the firm into the logic of the industrial society.

The economic theory of the firm can be summarized as follows. The entrepreneur is faced with a series of behavior alternatives. These alternatives are limited by the economic constraints of the market and the technological constraints of the production function. Within these constraints he will act in such a way as to maximize his economic profit. This behavior is facilitated by the personality characteristic of complete rationality and the information system characteristic of perfect knowledge. Finally, the individual so described is one who is entirely motivated by economic forces. A more subtle elaboration of this last point is the view that leisure has value and that a person will not work except in response to sufficient economic incentives. Thus, the classical economist specifically assumed that man was essentially "lazy" and preferred to minimize his work effort.[5]

Most modern economists would agree that the classical theory of the firm is based on several rather severe abstractions from the real world of business enterprise.[6] Nevertheless, despite these criticisms, there can be little doubt that it has had a substantial influence on the development of management philosophy and practice. The explanation of human behavior offered by economists—i.e., economic motivation and profit maximization—was incorporated into the patterns of thought of the merging industrial community where it not only became established in its own right but also provided the philosophical and psychological foundations of the scientific management movement.

[4] Robert L. Heilbroner, *The Worldly Philosophers,* rev. ed. (New York: Simon and Schuster, Inc., 1961), pp. 7–8.

[5] This assumption is the basis for the "backward-bending" labor supply curve found in the literature of economics.

[6] See, for example, Andreas G. Papandreou, "Some Basic Problems in the Theory of the Firm," in *A Survey of Contemporary Economics,* ed. Bernard F. Haley (Homewood, Ill.: Richard D. Irwin, Inc., 1952), Vol. II, 183–219.

Classical Organization Theory

At the turn of the century, Fredrick W. Taylor began a major investigation into the functioning of business organizations, which became known as the scientific management movement. Taylor's approach combined the basic behavioral assumptions of the economic theory of the firm with the viewpoint of the engineer seeking the most effective utilization of the physical resources at his disposal. He was concerned with men primarily as "adjuncts to machines" and was interested in maximizing the productivity of the worker through increased efficiency and reduced costs. Implicit in this approach was the belief that if men who might otherwise be wasteful and inefficient could be instructed in methods of achieving increased productivity and, at the same time, provided with adequate economic incentives and proper working conditions, they could be motivated to adopt the improvements, and the organization would benefit accordingly.[7]

March and Simon have noted that the ideas of the scientific management movement are based predominantly on a model of human behavior which assumes that "organization members, and particularly employees, are primarily *passive instruments*, capable of performing work and accepting directions, but not initiating action or exerting influence in any significant way."[8]

The scientific management movement flourished and rapidly became an important part of the business enterprise scene; in fact, for many years it virtually dominated this scene. Furthermore, even a brief glance at current management literature and practices should satisfy the reader that most of Taylor's views are still widely accepted today. Newer theories of management may have supplemented, but they have never entirely replaced, the scientific management approach.

About 1920 a second major pattern of organization theory, usually referred to as "principles of management" or "administrative management theory," began to develop. This body of doctrine adopted what was essentially a departmentalized approach to the problem of management. Its primary objective was the efficient assignment of organization activities to individual jobs and the grouping of these jobs by departments in such a way as to minimize the total cost of carrying on the activities of the firm. Writers of this school concerned themselves largely with the development of "principles of management" dealing with such subjects as lines of authority and responsibility, specialization, span of control, and unity of command.[9] This administrative management theory appears to have had a substantial and continuing influence on management theory and practice.

The work of Taylor and his scientific management successors led them into detailed studies of factory costs and provided an important stimulus for the development of modern cost and management accounting. Administrative management theory further contributed to this development through its emphasis on control and departmental responsibility and accountability. Finally, all of this occurred within the overall setting provided by the economic theory of the firm. In summary, it seems clear that with respect to both its philosophy and techniques, much of contemporary management accounting is a product of, and is geared to, these classical theories. This is what is referred to here as the "traditional management accounting model of the firm."

[7] James G. March and Herbert A. Simon, *Organizations* (New York: John Wiley & Sons, Inc., 1958), pp. 12ff.

[8] *Ibid.*, p. 6.

[9] *Ibid.*, pp. 22ff.

A Tentative Statement of Behavioral Assumptions Underlying Present-Day Management Accounting

It should now be possible to draw together the several strands of the preceding discussion and attempt to postulate some of the fundamental behavioral assumptions that appear to underlie the traditional management accounting model. These assumptions were presented in Table 1 above. The parenthetical notations note the major conceptual sources of the assumptions. In some cases there appears to be a considerable overlapping of sources; however, since this is not crucial to the present investigation, the notations have been limited to the primary or most significant area.

Some Behavioral Concepts of Modern Organization Theory

The preceding paragraphs were concerned with an effort to identify a set of behavioral assumptions which could be associated with current theory and practice in management accounting. We will now attempt to develop an alternative set of behavioral assumptions for management accounting—one that is based on concepts from modern organization theory.

Of the several different modern organization theory approaches, the "decision-making model" of the firm has been selected for use here. The basis for this choice is the close relationship which appears to exist between the decision-making model and the information-system concept of management accounting discussed earlier. The decision-making approach to organization theory effectively began with the writings of Chester I. Barnard, particularly in *The Functions of the Executive,* and was further developed by Simon and others.[10] The model is primarily concerned with the organizational processes of communication and decision making. While drawing heavily on sociology and psychology, it is distinguished from these organization theory approaches by its emphasis on the decision as the basic element of organization.

Organizations are viewed as cooperative efforts, or coalitions, entered into by individuals in order to achieve personal objectives which cannot be realized without such cooperation. These individuals are motivated to join the organization and contribute to the accomplishment of its objectives because they believe that in this way they can satisfy their personal goals. It is important to note that these personal goals include social and psychological, as well as economic, considerations. Thus, the survival and success of the organization depends on the maintenance of a favorable balance between the contributions required of each participant and the opportunities to satisfy personal goals which must be offered as inducements to secure effective participation.

It is common practice to speak of organization goals; however, to be completely precise, it is the participants who have goals. The organization itself is mindless and, therefore, can have no goals. In the sense that it is used here, the term "organization goals" is intended to mean the goals of the dominant members of the coalition, subject to those constraints which are imposed

[10] Chester I. Barnard, *The Functions of the Executive* (Cambridge, Mass.: Harvard University Press, 1938); Herbert A. Simon, *Administrative Behavior* (New York: John Wiley & Sons, Inc., 1947); March and Simon, *Organizations;* and Richard M. Cyert and James G. March, *A Behavioral Theory of the Firm* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1963). The preceding works represent the principal theoretical sources for the decision-making model discussed here.

by other participants and by the external environment. This view implies an organizational goal structure which is in a constant state of change as the environment and the balances and relationships among the participants change. Under such circumstances, it seems meaningless to talk of a single universal goal, such as profit maximization. To the extent that any long-run overall objective might be identified, it appears that this objective would have to be stated in very broad and general terms, such as the goal of organization survival.

The decision-making process is usually described as a sequence of three steps: (1) the evoking of alternative courses of action, (2) a consideration of the consequences of the evoked alternatives, and (3) the assignment of values to the various consequences.[11]

It has been suggested that any behavioral theory of rational choice must consider certain limits on the decision maker.[12] These include his (1) limited knowledge with respect to all possible alternatives and consequences, (2) limited cognitive ability, (3) constantly changing value structure, and (4) tendency to "satisfice" rather than maximize. Rational behavior, therefore, consists of searching among limited alternatives for a reasonable solution under conditions in which the consequences of action are uncertain.

The behavioral concepts which flow from the decision-making model have a number of interesting implications. For example, authority is viewed as something which is accepted from "below" rather than imposed from "above."[13] In other words, there must be a *decision to accept* authority before such authority can become effective. Further, human activity is considered to be essentially a process of problem-solving and adaptive behavior—a process in which goals, perception, and abilities are all interrelated and all continually changing.

To summarize the decision-making model, the basic element of organization study is the decision. The objective of managerial decision-making is to secure and coordinate effectively the contributions of other participants. This is accomplished by influencing, to the extent possible, their perception of alternatives and consequences of choice and their value structures, so that the resulting decisions are consistent with the current objectives of the dominant members of the organization.

While the theorists of the "decision-making" school have paid substantial attention to behavioral concepts, the literature does not appear to contain a detailed and complete statement of their underlying behavioral assumptions. Accordingly, it becomes necessary, as it was with the traditional accounting model, to abstract and formulate a set of assumptions. The modern organization theory assumptions presented in Table 2 represent an attempt by the present writer to identify and extend the behavioral assumptions of the decision-making model in terms of the management accounting function.

Basic Conflicts Between the Behavioral Assumptions of Traditional Management Accounting and Modern Organization Theory

An examination of the two sets of behavioral assumptions developed above suggests a number of interesting questions. Answers to these questions, however, can only be found through

[11] March and Simon, p. 82.

[12] Herbert A. Simon, *Administrative Behavior*, 2nd ed. (New York: The Macmillan Company, 1957), pp. xxv–xxvi.

[13] Douglas McGregor, *The Human Side of Enterprise* (New York: McGraw-Hill Book Company, 1960), pp. 158–60.

extended empirical analysis. Thus, whatever value attaches to the foregoing discussion appears to relate to its possible contribution in providing a theoretical framework for future empirical research. This research might be designed to explore such questions as the following:

1. What behavioral model provides the most realistic view of human behavior in business organizations? (Accountants should, perhaps, be willing to accept the research findings of organization theorists regarding this question.)
2. Is it possible to draw any general conclusions about the view of behavior actually held by accountants (and managers) in practice?
3. What, if any, are the major differences in the behavioral assumptions of the views in Tables 1 and 2, above?
4. What, if any, are the consequences for the organization and its participants of the differences in the behavioral assumptions of the views in Tables 1 and 2?
5. Is it possible to design management accounting systems which are based on a more realistic view of behavior, and would such systems produce better results than present systems?

Lacking empirical evidence, any attempt to investigate the implications of the differences between the two views of behavior discussed in this paper must be considered highly speculative. We might, however, examine briefly a few of the major differences in order to illustrate the nature of the problem. Let us assume for the moment that the decision-making model represents a more realistic view of human behavior than the traditional management accounting model. Let us further assume that the traditional model is a reasonably accurate summary of actual management accounting views in practice. Under these circumstances, what are some of the consequences for business organizations of the use of accounting systems based on the traditional management accounting model of behavior? The system of classification used in Tables 1 and 2 will also be adopted here. Thus, this analysis will concentrate on four major areas: organization goals, behavior of participants, behavior of management, and the role of accounting.

Assumptions with Respect to Organization Goals

In comparing these two sets of assumptions, the most immediately apparent difference concerns the relative simplicity and brevity of the traditional accounting assumptions as contrasted to those of the organization theory model. This should not be particularly surprising, since such a difference seems to be consistent with the general philosophies of the two models. There can be little doubt that the view of human behavior associated with the scientific management movement and classical economics is much less complicated than the behavioral outlooks of modern organization theory. In fact, the principal conflict between modern and classical organization theories appears to rest precisely on this issue. Since traditional management accounting is closely related to the classical models, it seems reasonable to expect that it will also tend toward a relatively simple and uncomplicated view of behavior. For example, with respect to organization goals, the behavioral assumptions of the accounting model focus on a single universal objective of business activity. The organization theory assumptions, on the other hand, suggest a much broader and rather imprecise structure of goals.

The traditional management accounting view of organization goals, which appears to be directly related to the theory of the firm of classical eco-

nomics, may be summarized as follows: The principal objective of business activity is the maximization of the economic profits of the enterprise; the total responsibility for the accomplishment of that objective can be divided into smaller portions and distributed to subunits throughout the organization; the maximization by each subunit of its particular portion of the profit responsibility will result in maximization of the total profits of the enterprise.

The entire structure of traditional management accounting appears to be built around this concept of profit maximization and the related (but quite different) idea of cost minimization. Management accountants have, for the most part, limited the scope of their systems to the selection, processing, and reporting of data concerning certain economic events, the effects of which can be reduced—without too many complications—to monetary terms. This approach is justifiable only if the particular class of events under consideration can be viewed as *the* critical variables affecting the organization. Thus, accountants have been able to rationalize the importance of the data flowing through their systems by relating these data and their use directly to the assumed goal of profit maximization. However, the classical economic view of profits as the universal motivating force of business enterprises has come under substantial attack in recent years. This attack has been based on two general issues. First, questions have been raised concerning the adequacy of economic profits as the sole significant explanation for what takes place within an organization. Second, it has been suggested that limitations on the decision-making process result in behavior which is best described as "satisficing" rather than maximizing.

It should be particularly emphasized that the recognition of a more complex goal structure does not mean that economic profits can be ignored. Obviously, business firms cannot survive for any extended period of time without some minimum level of profits. Nevertheless, the attempt to summarize the entire goal structure of a complex business entity through the use of one index may result in an overly simplified and unrealistic view of the organization. In short, profits may represent a necessary but not a sufficient definition of the goal structure of business organizations.

The view of organization goals, suggested by the behavioral assumptions of the decision-making model, has two major aspects. First, those objectives which are commonly referred to as goals of the organization are, in fact, the goals of the dominant group of participants. Secondly, it is suggested that these goals are the result of the interaction of a set of constantly changing forces. Thus, the goal structure of an organization is not only rather imperfectly defined at any given point in time but it is also in a continual process of change throughout time. In order to identify any truly universal goal, it may be necessary, as suggested earlier, to generalize to the very broad —and perhaps meaningless—level of an objective such as organization survival.

In view of the complex nature of organization goals, it is possible that the profit maximization assumption unduly restricts the role of management accounting to providing a limited and inadequate range of data for decision-making. It is as if the accountant were viewing the firm through a narrow aperture which permits him to observe only a thin "slice" of the total organization activity. In emphasizing this narrow view, traditional management accounting appears to ignore many of the complexities and interrelationships that make up the very substance of an organization. What is the practical

implication of these observations? How would management accounting change if accountants did not concentrate exclusively on profit maximization? It is likely that this, in itself, would not involve immediate operational changes but rather a change in underlying philosophy. As this philosophy is modified, it should become apparent that a number of specific changes in procedures and systems are in order. Examples of such specific changes might be found in the departmental budgeting and accounting techniques discussed below.

The traditional accounting assumption with respect to the divisibility and additivity of the responsibility for the accomplishment of organization goals seems to warrant some additional comment. Research in organization theory has indicated that individual members of an organization tend to identify with their immediate group rather than with the organization itself. This tendency appears to encourage the development of strong subunit loyalties and a concentration on the goals of the subunit even when these goals are in conflict with the interests of the organization. The usual departmental budgeting and accounting techniques, by which management accountants endeavor to measure the success of the various subunits within an organization in achieving certain goals, are based on the assumption that profit maximization or cost minimization at the departmental level will lead to a similar result for the firm as a whole. Thus, accounting reports tend to highlight supposed departmental efficiencies and inefficiencies. Reports of this type seem to encourage departmental activities aimed at "making a good showing" regardless of the effect on the entire organization. It appears to be common for departments within an organization to be in a state of competition with each other for funds, recognition, authority, and so forth. Under such circumstances it is not very likely that the cooperative efforts necessary to the efficient functioning of the organization as a whole will be furthered by an accounting system which emphasizes and, perhaps, even fosters interdepartmental conflicts.

The tendency for intraorganizational conflict appears to be further compounded by some of the common management accounting techniques for the allocation and control of costs. For example, in some organizations with relatively rigid budgeting procedures, it appears to be a normal practice for departments to attempt deliberately to use up their entire budget for a given period in order to avoid a reduction in the budgets of succeeding periods. Another example is the emphasis often placed on the desirability of keeping costs below some predetermined amount. In such cases, it is likely that, even though a departmental expenditure would be extremely beneficial to an organization, it will not be undertaken if such action would cause the costs of that department to exceed the predetermined limit.

Assumptions with Respect to the Behavior of Participants

The view of the individual inherent in the behavioral assumptions associated with traditional management accounting is one which has been completely rejected by most of the behavioral scientists interested in modern organization theory. To what extent this traditional view is actually held by accountaints in practice is a question which, as stated earlier, can only be answered by empirical investigation. Our own limited experience suggests that it is held by a sufficient number of management accountants to be considered at least a significant view within the profession.

It is possible that the failure of management accountants to consider the more complex motivating forces which organization theory recognizes in the individual contributes to the use of accounting systems and procedures which produce "side effects" in the form of a variety of unanticipated and undesired responses from participants. For example, many management accounting techniques intended to control costs, such as budgeting and standard costing, may virtually defeat themselves because they help to create feelings of confusion, frustration, suspicion, and hostility. These techniques may not motivate effectively because they fail to consider the broad spectrum of needs and drives of the participants.[14]

Assumptions with Respect to the Behavior of Management

Modern organization theory encompasses a view of the management process which differs substantially from the "classical" view associated here with management accounting. It is interesting, however, that both models appear to take essentially the same position with respect to the basic purpose of managerial activity. This purpose relates to securing effective participation from the other members of the organization. One way of emphasizing the nature of the conflict between the two models in this regard is to examine the manner in which each attempts to accomplish this basic purpose.

According to the traditional accounting model, management must control the performance of others—the principal instrument of control being authority. This model assumes that participants must be continually prodded to perform and that this prodding is accomplished through the use of authority which is applied from above. Also, it places heavy reliance on the use of economic rewards and penalties as devices to implement authority and motivate effective participation.

The decision-making model, on the other hand, assumes that management must *influence* the behavior of others. Furthermore, this approach suggests that, unless individuals are willing to accept such influence, effective participation cannot be assured regardless of the extent of the formal (classical) authority available to management. Viewed in this sense, meaningful authority cannot be imposed on a participant; rather, it must be accepted by him. Finally, the decision-making model assumes that the willingness of participants to accept authority and to make effective contributions to the organization depends not only on economic considerations but also, to a substantial extent, on social and psychological factors.

There seems to be a very close relationship between the behavioral assumptions of traditional management accounting and those associated with the classical management view of the firm. This is evidenced not only in their historical development but also by the manner in which management and management accounting currently interact in the modern business organization. It appears reasonable to expect that the effect of this interaction is to strengthen a jointly shared philosophy with respect to human behavior and the role of management. Managers who tend toward the classical view of behavior are likely to find support from traditional accounting systems which provide the kinds of data that emphasize this view. This accounting emphasis in turn probably serves to focus the attention of management on issues and

[14] For a discussion of the behavioral implications of budgets, see Andrew C. Stedry, *Budget Control and Cost Behavior* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960).

solutions which are consistent with the philosophy of the classical view. Thus, a "feedback loop" is established which appears to be an important factor in perpetuating this relatively narrow view of human behavior among both management and accountants.

Since the assumptions of the traditional accounting model are so close to classical organization theory and, in fact, appear to be a reasonably good description of the classical theory itself, it would be interesting to consider two questions. First, does the classical view of management provide an efficient solution to the problems of influencing behavior within an organization? Second, if the principal function of management accounting is to furnish relevant data for managerial decision making, should the accountant be concerned with providing the kinds of information that management actually wants or the kinds of information that management should want?

With respect to the first question, this paper has attempted to demonstrate that the classical view may not be an efficient approach in motivating organizationally desirable behavior. This premise appears to be supported by a substantial amount of theoretical and empirical research in modern organization theory. In terms of the present discussion, the important point is that traditional management accounting procedures and attitudes cannot be justified solely on the basis that they are consistent with other common management practices because serious questions have been raised regarding the desirability of many of these practices themselves.

In reference to the second question posed above, it can be argued that it is the task of management accounting to provide the information desired by management and to provide it in a manner which is consistent with existing management philosophy. In other words, it is not the responsibility of the accountant to attempt to change the viewpoint of management but only to function within the framework established by this viewpoint. The difficulty with this argument is that it treats accounting as something separate from management. This paper, on the other hand, assumes that management accounting is an integral part of management. The adoption of a more realistic model of behavior by accountants could place them in the position of leading rather than passively following the changes in management philosophy which are bound to occur as a result of the impact of modern organization theory. Thus, it might be hoped that the development of more sophisticated management accounting systems would encourage the evolution of a much more sophisticated management viewpoint in general.

Assumptions with Respect to the Role of Accounting

Modern economic organizations are, of course, highly complex entities. Business managers must continually operate under conditions of uncertainty and limited rationality. In addition, management accountants are subject to the same kinds of drives and needs as are other members of the organization. All of this suggests that management accounting systems could not, even under the best of circumstances, achieve the degree of certainty, neutrality, and objectivity that is often attributed to them. To the extent that management accounting fails to live up to its image in this regard, it can be anticipated that problems will arise for the organization. For one thing, organization members are often subject to evaluations based on information produced by the accounting system. These individuals are likely to be seriously con-

fused and disturbed by a flow of seemingly precise and exact accounting data which they cannot really understand or explain, but which nevertheless imply that they are (or are not) performing their tasks properly. The better education of organization participants regarding the limitations of accounting data, while worthwhile in its own right, does not represent an adequate solution. A much more important step would be a clearer understanding of these limitations by accountants themselves.

Also, as members of the organizations which they serve, management accountants can be expected to seek such psychological and social objectives as security, prestige, and power. In some instances, they might also be expected —as suggested by the discussion of subunit goals—to view the success of the accounting department and the technical perfection of the accounting process as ends in themselves. Thus, it is possible that some management accountants tend to view their function as primarily one of criticizing the actions of others and of placing the responsibility for failures to achieve certain desired levels of performance. Where this tendency exists, it may be expected to have a significant effect on motivation and be a major source of difficulty within the organization.[15]

Conclusions

This paper has attempted to postulate a set of behavioral assumptions which could be associated with the theory and practice of "traditional" management accounting. The resulting set of fifteen assumptions represents an accounting adaptation of what might be termed the classical view of human behavior in business organizations. This view emphasizes such concepts as profit maximization, economic incentives, and the inherent laziness and inefficiency of organization participants. It is a model which is structured primarily in terms of the classical ideas of departmentalization, authority, responsibility, and control. The accounting process which has emerged in response to the needs presented by this classical model appears to treat human behavior and goals essentially as given. Further, the generally accepted measure of "good" accounting seems to be one of relevance and usefulness in the maximization of the money profits of the enterprise.

In addition, we have examined a set of behavioral assumptions based on research in modern organization theory. It seems clear that a management accounting system structured around this second set of behavioral assumptions would differ in many respects from the accounting systems found in practice and described in the literature.

One should not infer that the traditional assumptions considered here are completely invalid. The very fact that they have endured for so long suggests that this is not the case. It should at least be recognized, however, that in many respects the extent of their validity may be subject to question. Also, it is not argued that all accountants limit themselves at all times to this traditional view. Rather, the two sets of behavioral assumptions discussed might be considered as extreme points on a scale of many possible views. The significance of the traditional point on such a scale appears to be twofold: (a) it is likely that the traditional model represents a view of behavior which is relatively common in practice, and (b) this view seems to underlie much of what is written and taught about accounting.

If the modern organization theory

[15] Chris Argyris, *The Impact of Budgets on People* (Ithaca, N. Y.: Prepared for The Controllership Foundation at Cornell University, 1952).

model does ultimately prove to be a more realistic view of human behavior in business organizations, there is little doubt that the scope of management accounting theory and practice will need to be expanded and broadened. In particular, accountants will have to develop an increased awareness and understanding of the complex social and psychological motivations and limitations of organization participants. What is urgently needed, and what we have had very little of in the past, is solid empirical research designed to measure the effectiveness with which management accounting systems do, in fact, perform their functions of motivating, explaining, and predicting human behavior.

THE EFFECTS OF ACCOUNTING ALTERNATIVES ON MANAGEMENT DECISIONS

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A theoretical analysis of the relationship between the accounting and decision-making processes of the firm is presented. Conditions under which variations in accounting methods produce different decisions and conditions that produce no effect are analyzed. Lack of feedback, functional fixation on the part of decision-makers, and an ill-structured environment can each contribute to misinterpretation of accounting data.

1. Introduction

A growing interest has arisen among accountants in understanding accounting in relation to the entire business decision process. They have questioned such factors as the role of accounting in the whole complex process of deci-

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sion making in business and what effects, if any, different accounting methods have on this decision process. Research has been aimed at finding out if decisions made in an organization can be influenced by changing its accounting system.

Until recently discussions of alternative accounting methods have been directed primarily toward how outputs from accounting systems differ, depending upon the accounting methods that are used. We know that in many cases LIFO and FIFO can result in different inventory values and, hence, will produce different profit figures even though the firm operates in an identical business environment. But a more important question is whether these different profit figures affect managers' decisions and, if so, under what conditions? Unless we can show that the different figures (or more precisely different patterns of figures) lead to different decisions under a given set of conditions, there is no point in arguing the merits or demerits of alternative accounting methods.

Some recent studies have been directed toward understanding how differences in the data affect the behavior of the users. Bonini (1) carried out a simulation of business activity based on some assumptions about how business managers behave and found that a firm with the LIFO inventory method tends to generate more profit under given conditions than a firm with the average cost method of inventory valuation. The reasoning behind this finding is that the LIFO inventory method increases the variability of profits from period to period more than does the average cost inventory method, and, hence, it stimulates more attention and pressures by managers toward better profit.

On the other hand, the experimental study by Bruns (2) leads to contradictory conclusions. He found that there is no apparent relationship between inventory valuation methods and managers' decisions on selling price, promotion, production volume, etc. An even more recent experiment by Dyckman (7) also came to the same conclusions.

It is, however, difficult to derive general statements from the results of these three studies concerning the influence of different accounting methods upon managers' decisions. We cannot conclude from Bonini's study that the LIFO method should be preferred to the average cost method of inventory valuation because the former tends to generate higher levels of profits, nor can we conclude from Bruns's study or Dyckman's study that inventory valuation methods have no effect on business decisions. Accounting variations may have significant effects under some conditions, and may have no effect under other conditions. The basic problem in these studies is an inability to generalize from a single case.

Therefore, an even more important question than whether different accounting methods have *any* effects upon decisions is: *Under what conditions do variations in accounting methods produce different decisions,* and *why* are (or *are not*) different decisions produced by using different accounting methods?

In order to answer these questions, we need, in addition to empirical studies, a theoretical clarification of the mechanism by which an accounting process and a decision-making process are related. The purpose of this paper is to develop a theoretical analysis of the relationship between the accounting and decision-making processes of a firm. This analysis is then used to study the effect of alternative accounting methods on managers' decisions. Instead of analyzing one empirical situation and deriving conclusions based on that particular example, we have derived some general conditions under which alternative ac-

counting methods do have an effect upon the decision-making process and other conditions under which different accounting methods do not have any effect. For each individual empirical situation we are then able to specify a set of variables which will allow us to predict whether or not alternative accounting methods have an effect upon management decisions. In the following section we concentrate on the role of information in the decision-making process. In Parts 3 and 4, respectively, the effects on decisions of (1) *changes* in accounting method and (2) *alternative* accounting methods are discussed.

2. The Role of Information in the Decision Process

2.1. The Decision Process as a Function

A decision process is characterized by three factors: (a) decision inputs, (b) decision outputs, and (c) a decision rule. Decision inputs are factors which are considered by the decision-maker in making his decision. Decision outputs are decisions made by the decision-maker. A decision rule is a rule by which a set of decisions is associated with a set of decision inputs. For example, in an investment decision, let us assume that investments are to be based only upon the rate of return of the project (say, invest if the rate of return is greater than or equal to 15 per cent per year; otherwise, do not invest). Here the decision input is the project's rate of return, and the decision output is either "invest" or "do not invest." The decision rule is to associate all rates of return greater than or equal to 15 per cent per year with the decision output "invest" and all other rates of return with the decision output "do not invest."

Of course, an actual investment decision will be much more complicated involving many other decision inputs and outputs. However, suppose if we focus on only one input (e.g., rate of return) and one output (e.g., invest or do not invest), keeping other decision inputs constant, then it would be reasonable to assume that there is a relationship between the value of the input and the value of the output which is relatively stable for some period of time. This is what is meant by a decision rule.

If we let x represent a variable for the input and z a variable for the output, then the decision rule concerning the input x and the output z can be represented as a function h as follows:

$$z = h(x) \qquad (1)$$

In an actual decision process, the value of the output for a given value of the input may not be unique; that is, the function h may not be single-valued. For example, the decision-maker may decide to invest on a project A and decide not to invest on a project B, even though the two projects have an identical rate of return. In this case a single value of the decision input yields two different values of the decision output, i.e., "invest" and "do not invest"; that is, the decision function is not single-valued. However, we may assume that by making finer specifications on the environmental conditions (i.e., the values of other decision inputs) under which the decision function is supposed to be applied, it can eventually be converted into a single-valued function. We shall, therefore, deal with only a single-valued function in the following analysis.

2.2. Principals versus Surrogates as Decisions Inputs

In order to understand the role of accounting data in a decision process, it is crucial to distinguish between

principal decision inputs and *surrogated* decision inputs. We will emphasize that accounting data are generally surrogated inputs rather than principal inputs.

By a principal input, or a principal, we mean a decision input upon which the decision-maker *wants* to base his decision ultimately. A surrogated input, or a surrogate, is a decision input upon which the decision-maker bases his decision *only insofar as the surrogate reflects a principal.*[1]

For example, a thermometer reading is a surrogate for a temperature reading. We want to base our decision upon the thermometer reading only insofar as it reflects the real temperature. Similarly, in a pricing decision the decision-maker may want to base his decision upon the cost of the product that is reported in an accounting statement only to the extent that the reported cost reflects what he considers to be the "real" cost of the item.

For a given principal, there may be a hierarchy of surrogates which reflect the principal. For instance, if the reported sales volume of the firm reflects the reported profit of the firm which, in turn, reflects the real profit of the firm, the decision-maker may base his decisions upon this indirect surrogate, the reported sales volume, as a surrogate of the real profit to the firm.

2.3. *Characteristics Required for a Surrogate*

Obviously, in order to effectively use a surrogate instead of a principal in a decision process, the surrogate must have certain characteristics. We now want to investigate these characteristics.

[1] *Webster's Seventh New Collegiate Dictionary* defines a surrogate as a substitute to be put in place of another. Also see Charnes and Cooper (3, p. 369) for a further elaboration on the relationship between the principal and its surrogates.

2.3.1 IDENTIFIABLITY. The surrogate must reflect the principal input. Since the decision-maker wants to base his decision upon the principal input, it is necessary for him to be able to estimate the value of the principal input from the value of the surrogated input. More precisely, the decision-maker must be able to use the surrogate to identify the key factors necessary for his decision. In the above example of the investment decision, the decision-maker can use any input as a surrogate for the rate of return if, and only if, he can identify whether the rate of return is greater than or equal to 15 per cent per year. Note that in this case it is not necessary that the decision-maker be able to identify the exact value of the rate of return. For decision purposes he only needs to know whether the rate of return is greater than or equal to 15 per cent per year. This is what we mean by the decision-maker being [able] to obtain *the key factors which affect the decision.* A surrogate which reflects the principal in this sense will be called a "satisfactory surrogate." Obviously, whether or not a surrogate is satisfactory depends not only upon the surrogate-principal relationship but also upon the decision function which defines the key factors of the principal input.[2]

The notion of *identifiability* (of the

[2] Since it is not the purpose of this paper to analyze the functional relationship between a surrogate and a principal, the above statements are not as precise as they otherwise should be. The readers who are interested in pursuing this topic in a more rigorous manner are referred to Ijiri (11), where the notions of a perfect, a satisfactory, and a reasonable measure are defined, based upon the functional relationship involved. Also refer to Ijiri (12), where the relationship between a management goal and an accounting indicator as a surrogate for the goal is analyzed. The analysis is called "goal analysis," which is an extension of break-even analysis.

key factors for the decision) raises the question of the reliability of the surrogate-principal relationship. The surrogate-principal relationship can be represented by

$$y = f(x) \qquad (2)$$

where x is a variable representing the principal input, y a variable representing the surrogated input, and f a function representing the surrogate-principal relationship. This relationship is reliable if it is *stable* enough so that the decision-maker can *identify* the key factors of the principal input from the value of the surrogate. We can use again our earlier example of the investment decision. An unstable surrogate is one where, for example, a value of 15 per cent means that the real rate of return of the project is 19 per cent per year at one time and the same value of 15 per cent means that the real rate of return of the project is 12 per cent per year at another time. When this *unstable* condition arises, the decision-maker can no longer rely upon the value of the surrogate in making his investment decision. An example of this situation is the use of the payback factor as a surrogate for the rate of return. That is, a payback factor of 3 gives a rate of return of 12 per cent (approximately) if the life of the project is four years. On the other hand, the same payback factor of 3 gives a rate of return of 19 per cent (approximately) if the life of the project is five years. In this case the decision-maker cannot *rely* on this surrogate only, because he cannot *identify* the key factor which affects his decision.[3]

[3] Refer to Ijiri and Jaedicke (13), where the reliability of an accounting system is discussed by using statistical concepts. Here, for our subsequent discussions, it is sufficient to define reliability as the possibility of identifying the *key factors* of the principal input *consistently* from the value of the surrogate.

2.3.2 Timing. In addition to the requirement of identifiability, a surrogate must be available to the decision-maker at the time of the decision; that is, the surrogate must meet the requirement of *timing*. The significance of this requirement is made clearer in the following discussion on the *need* for a surrogate in a decision process.

2.4. Need for a Surrogate in a Decision Process

Why does a decision-maker need a surrogate? That is, why doesn't he always use the principal input in his decision process? The following cases summarize those instances in which the decision-maker needs a surrogated input.

Case 1. Difficulty in Obtaining the Principal. When it is too expensive (either timewise or costwise or both) for the decision-maker to use the principal input in making his decision or when it is practically impossible for him to obtain the principal input, a surrogated input will be preferred to the principal. For example, a bank manager may be willing to base his lending decisions upon financial statements certified by a C.P.A. even if he has the right to perform an independent investigation and the necessary auditing talent to do so.[4]

Furthermore, when the value of a principal is not available at the time of the decision, it is necessary for the

[4] Here again, the reliability of real world data that are used in decision making is often not as satisfactory as that defined above. Occasionally, one may use an unsatisfactory surrogate which sometimes leads to a wrong decision. We often tolerate such a case if the wrong decision does not lead to a fatal outcome and if the cost of obtaining the unsatisfactory surrogate is much cheaper than the cost of obtaining a completely satisfactory surrogate. For a discussion of the use of unsatisfactory surrogates, see Ijiri (11) and (12).

decision-maker to use a surrogate insofar as he does not want to delay the decision (time lag). For example, if the profit figure of a division cannot be made available until the end of the month, the division manager may want to base his decision upon a surrogate, such as the sales volume to date (which may be available on the daily basis). Another example is the use of a predetermined overhead rate as a surrogate for the "actual" overhead rate which is not available until the end of the accounting period.

CASE 2. DIFFICULTY IN USING THE PRINCIPAL. A surrogate may be used to simplify a decision problem where the decision-maker may actually want to base his decision on a large number of inputs. This will occur when the number of inputs to be considered exceeds the capacity of the decision-maker. It is a well-known fact that a human being can use effectively only a limited number of inputs in making his decision.[5] If the decision environment is too complicated, the decision-maker is likely to simplify the problem by grouping or aggregating a number of factors or by simply neglecting some of them. For example, a president of a firm may be able to obtain detailed data on the activities of the firm without too much cost, but he may want to base his decision upon a summary statement prepared by an accountant. The use of a representative figure, such as a mean, median, mode, maximum, minimum, variance of a set of data, is an example of the use of a surrogate to reflect many different principal inputs.

2.5. Surrogate-Principal Relationship: Cause and Effect

In discussing the surrogate-principal relationship earlier, we avoided any mention of the cause-and-effect problem. In the case of accounting data as surrogates, it is usually the principal which determines the value of the surrogate. That is, the principal is usually the cause and the surrogate (the accounting report or reported amount) is the effect. Therefore, the usual functional relationship is

$$x \xrightarrow{f} y \tag{3}$$

where x represents the principal input, y the surrogated input, f the functional relationship between x and y, and the arrow the fact that x is the cause of y.

However, this cause-and-effect relationship is occasionally reversed. The following two examples illustrate situations where this can occur.

EXAMPLE 1. A division manager wants to exercise more pressure upon his subordinates if the manager's supervisor feels that the performance of the manager's division is unsatisfactory. In other words, his supervisor's evaluation (x) of the division is the principal for the manager's decision as to the amount of pressure (z) that he exerts on his subordinate, namely,

$$x \xrightarrow{h} z \tag{4}$$

Suppose that the division manager knows, however, that the supervisor's evaluation (x) is based upon the reported divisional profit (y) i.e., $x = \phi(y)$. Then the division manager may want to base his decision (z) upon the reported profit as a surrogate of the supervisor's evaluation $(z = g(y))$. In this case, the surrogate (y) is the cause of the principal (x):

$$x \xleftarrow{\phi} y \xrightarrow{g} z \tag{5}$$

Supervisor's Evaluation — Reported Profit — Amount of Pressure

whereas in an ordinary case we have

$$x \xrightarrow{f} y \xrightarrow{g} z \tag{6}$$

Principal — Surrogate — Decision

[5] See, for example, Simon (17, pp. 241–60) and Garner (8, pp. 98–187).

EXAMPLE 2. As another situation where the principal input is caused by a surrogate (rather than vice versa), consider the role of income taxes in decisions. The income tax is based on the reported profit which is a surrogate for the real profit. Yet the income tax may be a principal input for many decisions. If the decision-maker bases his decision (e.g., the amount of money to be borrowed from banks) upon the reported profit as a surrogate for the actual income tax, the situation may be represented as follows:

$$x \xleftarrow{\phi} y \xrightarrow{g} z \qquad (7)$$

Income Taxes — Reported Profit — Amount of Loans

To summarize, we have identified two different surrogate functional relationships. One relationship is where the surrogate (y) is determined by the principal (x). That is,

$$x \xrightarrow{f} y$$

The other relationship is where the surrogate (y) causes the principal (x). That is,

$$y \xrightarrow{\phi} x$$

The value of the surrogate resulting from the former relationship represents the principal, which is a *past* state or event. In the latter case the value of the surrogate is used to *predict* the principal, which is a *future* state or event. Let us distinguish between the two types of surrogates (or more precisely the two types of uses of surrogates) by calling the former a "descriptive" surrogate and the latter a "predictive" surrogate. For example, the reported profit is a descriptive surrogate of the operations of the firm but is a predictive surrogate of its future profit.

However, whether a given surrogate is a descriptive surrogate or a predictive surrogate of a given principal may be more complicated than in the cases described above. Consider the situation in which a decision-maker wants to base his price decision on the real *future* cost. Since the real future cost is unknown at the time of his decision, he may use a measure of the real *current* cost. In this case, the real current cost would be a *predictive* surrogate and not a descriptive surrogate. On the other hand, the decision-maker may use the reported (accounting) cost as a *descriptive* surrogate of the real current cost. In this case, the reported cost is a descriptive surrogate of the real current cost, which is a *predictive* surrogate of the real future cost.

In an earlier section we stated the timing requirements for a surrogate: It must be available to the decision-maker at the time of his decision. When a decision-maker needs to base his decision upon factors in the future, the use of a predictive surrogate is obviously necessary and highly important. In fact, where it may be possible to eliminate a descriptive surrogate from the decision process by actually observing the principal, it is never possible to eliminate a predictive surrogate if the decision must be based on a factor that will occur in the future.

3. Effects of a Change in Accounting Method on Management Decisions

3.1. Accounting and Decision Processes

In Part 2 we analyzed the role of surrogates in the decision process. Accounting data as well as other types of business information are surrogates which the decision-maker uses to carry out the decision process. Of course, he will want to use surrogates only insofar as they reflect principal inputs (as discussed in the previous section).

To illustrate the interaction between an accounting process and a decision process, let us consider the following simplified example. Suppose that a decision-maker wants to quote a price (z) on each job so as to recover 300 per cent of the direct cost for the job (x). In the absence of a surrogate, his decision process is represented by

$$z = 3x \tag{8}$$

Suppose also that the firm's accounting process provides the full cost (y) for each job by adding to the direct cost a standard overhead which is 100 per cent of the direct cost (x). Then this accounting process is represented by

$$y = 2x \tag{9}$$

If the decision-maker wants to achieve the same result by basing his decision upon the surrogate (the full cost) instead of the principal (the direct cost), he must adjust his decision so that he quotes a price equal to 150 per cent of the full cost of the job, i.e.,

$$z = 1.5y \tag{10}$$

Therefore, the accounting process and the decision process collectively constitute the decision process that the manager would use in the absence of a surrogate. Namely, the decision process which was formerly

$$x \xrightarrow{3x} z \tag{11}$$

is now decomposed as

$$x \xrightarrow{2x} y \xrightarrow{1.5y} z \tag{12}$$

If the accounting process is changed and the full cost (y) is calculated as 150 per cent of the direct cost (x) instead of 200 per cent, the decision-maker must adjust his decision process from $z = 1.5y$ to $z = 2y$ in order to keep the overall process ($z = 3x$) unchanged.

Obviously, this is an extremely over-simplified example, but nonetheless it shows the important interaction between the accounting process and the decision process, i.e., *the decision-maker must, in general, adjust his decision process* (g) *when the accounting process* (f) *is changed if he wants to keep the overall process* (h) *unchanged.*

3.2. The Decision-Maker's Adjustment to a Change in an Accounting Method

Using the relationship between the accounting process and the decision process as described above, we can now discuss the central question to be investigated. Under what conditions can (or cannot) a decision-maker adjust his decision process (g) to a change in the accounting process (f)? We will discuss this question by considering two different factors that would indicate when the manager cannot adjust. One is the lack of feedback on the performance of the accounting process, and the other factor is the possibility of "functional fixation" on the accounting concepts and measurements that are used in the decision process.

3.2.1 Lack of Feedback. A key factor which will determine whether or not the decision-maker can adjust to a change in the accounting process is simply whether or not he receives appropriate feedback on the performance of the accounting process. That is, he must be able to determine whether the process is performing as he expects it to perform. A type of direct feedback is for the decision-maker to observe the value of the principal input and compare it with the value of the surrogate. A cash count or a physical inventory is a good example of direct feedback. In addition to direct feedback, a decision-maker often has a means of obtaining indirect feedback. Instead of checking the process by himself, he may

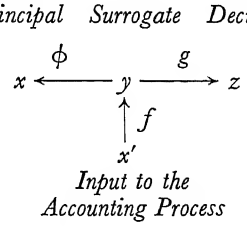
have somebody who checks the process for him. The use of an auditor to check any significant change in the accounting process is one way which might be used to discover when the accounting method is performing differently from what it is supposed to perform. Stockholders who, in their decisions, use profit figures as reported in financial statements are protected by auditors who report any significant changes in the accounting method used in generating profit figures. The decision-maker may have a number of surrogates which will collectively indicate any irregular performance of the accounting process, or an unexpected outcome from a decision may cause him to investigate the accounting process in detail.

It seems almost inconceivable to have a situation in business where a decision-maker has absolutely *no* feedback whatsoever on the performance of the accounting process. Therefore, it is highly unlikely to have a decision change which results solely from a change in an accounting process, where this is *caused only by the lack of feedback to the decision-maker.* This is especially true if we exclude a possible short-run effect due to the time lag between the change in the accounting process and the indication of the change to the decision-maker through feedback.

Therefore, if a modification in the accounting process results in any change in the decisions even though proper feedback exists for the decision-maker, it must be attributable to his inability to *use* the feedback in order to adjust to the alteration. No matter how good the feedback is in indicating the change, if the decision-maker cannot effectively use this feedback, he cannot hope to make the same decisions as before. There do appear to be instances in which decision-makers are unable to adjust. We believe the inability to adjust, when it exists, can be explained by a psychological factor called "functional fixation."

3.2.2 Functional Fixation. Psychologists have found that there appears to be "functional fixation" in most human behavior in which the person attaches a meaning to a title or object (e.g., manufacturing cost) and is unable to see alternative meanings or uses. People intuitively associate a value with an item through past experience and often do not recognize that the value of the item depends, in fact, upon the particular moment in time and may be significantly different from what it was in the past. Therefore, when a person is placed in a new situation, he views the object or term as used previously.[6] If the outputs from different accounting methods are called by the same name, such as profit, cost, etc., people who do not understand accounting will tend to neglect the fact that alternative methods may have been used to prepare the outputs. In such cases, a change in the accounting process clearly influences the decisions.

When accounting data are used as predictive surrogates, the accounting process represented by the function f does not come directly into the principal-surrogate decision relationship, as shown below:



However, if the functional fixation occurs on the ϕ-function (i.e., if the ϕ-function remains the same even after the f-function has been changed), then

[6] This phenomenon was discussed by Duncker (6).

a change in the f-function affects the principal (x); this, in turn, affects the decision (z). For instance, in Example 1 in Section 2.5, if the supervisor is unable to adjust to the change in the accounting process which generates the reported profit and continues to evaluate the division in the same manner (specified by the ϕ-function) as before, even though the meaning of the reported profit has now been changed significantly, then the change in the accounting process of generating the reported profit will influence the amount of pressure exerted by the division manager. Such an influence occurs even if the division manager himself is perfectly capable of adjusting his decision function (g) to the change in the accounting process (f), since what he is concerned with is not the performance of his division per se (which is the input x' to the accounting process) but his supervisor's evaluation (x) of his divisional performance.

4. Effect of Accounting Alternatives on Management Decisions

In the preceding section we discussed the question of whether or not a *change* in accounting methods affects management decisions. Our conclusion is that an accounting change will not affect decisions if there is feedback on the performance of the accounting system and if there is no functional fixation; i.e., the manager is able to effectively *use* the feedback information. A second question of great importance is whether or not the *choice* of one method from a set of accounting alternatives has any influence on the management decisions.

As a first step we will analyze one set of environmental conditions where existing research shows us that the choice of accounting method definitely affects decisions. This set of conditions can be referred to as an "ill-structured environment."

4.2. *Decision Making in an Ill-Structured Environment*

Authors who write about the management decision environment point out the ill-structured nature of the problems that confront business managers. That is, in today's business world, managers face problems for which there is great uncertainty about which alternatives are available and what constitutes an acceptable solution. Leavitt explains that in most managerial situations the decision-makers do not have a decision criterion that enables them to know exactly when they have made the correct decision.[7] Some of the reason for the ambiguity is that there is usually a long delay between a positive step (a decision) and the recorded outcome. Then, too, there are many events that occur simultaneously in the organization which makes it almost impossible to determine the results of one particular decision. Therefore, as the manager views his world, he is always faced with the question—would another action have worked better? This difficulty means that the manager cannot unambiguously determine the decision function [in (1) $z = h(x)$] that he *should* use.

Recent research describing how people behave in ill-structured or uncertain situations has shed some light on how people probably use accounting information in the ill-structured situations.[8] The results show that when a person is confronted by such a situation, it is unlikely that he will remain in it very long. He will use his previous experi-

[7] Leavitt (15, pp. 352–54).

[8] See, for example, Knight (14) and Cyert and March (4).

ence, available data, friends, etc. to define and structure his situation.[9] This problem is closely related to the one presented in section 2.4., where we discussed the limits of the human decision-making capacity. There we emphasized that the human mind can handle only a limited amount of information. We mentioned that humans simplify their problems by using surrogates which are aggregates of a number of principals or by neglecting some of the principals. These procedures represent two of the methods which the individual uses to define and structure his world.

Studies that have described a manager's actual decision-making behavior have found that he tries to avoid uncertainty and arrange the environment so that it has a predictable future. This is usually done in an organization by creating and following "standard operating procedures" in order to perform roles "safely."[10] The "standard operating procedures" are used to operationally define the decision-maker's environment and thus remove him from the previously ill-structured situation. We will now show how accounting information will sometimes be used to determine a decision-maker's "standard operating procedures," that is, *to define the goals and decision procedures of the manager.*

We find that the surrogates generated by accountants often become used as predictive surrogates to define the decision-maker's environment, his goals, and decision procedures. We mentioned (in the initial presentation of the concept of predictive surrogates in Section 2.5.) the example in which the reported profit determined the goals of the division manager $(x = \phi(y))$, since the supervisor used the reported profit as a basis for the evaluation of the division manager, and not what he considers as the "real" profit.

Another way that an accounting system determines the goals for a manager is by defining an area for him to pay attention to. For example, let us assume the accountants suddenly report scrap cost for the first time. The manager now modifies his goals in that he creates a new goal that specifies his objectives in regard to the control of scrap cost. In this example, the manager's g-function changes to incorporate the new piece of accounting data. Furthermore, the accounting procedure, in addition to specifying goals for a manager, may also be used by him to help define his decision function. If the accountant chooses to report a given set of surrogates, this set may provide a basis around which the manager structures his decision process. In these cases, we expect that alternative accounting methods will affect the manager's decisions.

There are examples in the behavioral science literature that describe situations where accounting information has been used in the way we have just described and has been found to influence both the goals of the decision-maker and the alternatives which he considers in making his decisions. Ridgway, studying the problem of accounting measures and behavior in American industry, found that "even where performance measures are instituted purely for purposes of information, they are probably interpreted as definitions of the important aspects of that job."[11] The results of Ridgway's study represent direct support for the theoretical framework that we have presented in this section.

[9] Refer to Knight (14) for a further elaboration of this topic.

[10] See Cyert and March (4).

[11] Ridgway (16, p. 377).

Additional support for our analysis comes from studies of the behavior in Russian industrial firms. These studies show that when specific performance surrogates are provided, they are used by the decision-maker to structure his uncertain world. Smolinski reports how "the project of the Novo Lipetsk steel mill...comprises 91 volumes totaling 70,000 pages. (One is not surprised to learn that the designers are paid by sheet....) Literally, everything is anticipated in these blueprints, the emplacement of each nail, lamp, or washstand. Only one aspect of the project is not considered at all: its economic effectiveness."[12] What Smolinski shows is, that by measuring and recording the number of pages in a report, this surrogate has become a factor that defines the decision-maker's world. The decision-maker then restricts his goals and alternatives to ones other than those which are most useful for the organization.[13]

In a study of the Russian executive, Granick points out several dramatic shortcomings of a system where pressures result in the decision-maker receiving a limited number of performance surrogates, and these are then used to determine his goals and alternatives. Granick discusses the "standard operating practice" of "storming," the phenomenon of getting everything possible out at the end of the month because monthly bonuses are determined by the volume produced.[14] He found that the volume of production was used as a descriptive surrogate of other principals that should have been considered by the decision-maker in determining his overall effectiveness. The result of the limited accounting information available to the Russian managers shows how these accounting systems greatly influence the behavior of the decision-maker in an ill-structured situation. Phenomena similar to that observed in Russia frequently are found in the United States, where surrogates, such as direct cost as a percentage of total cost, scrap costs, maintenance costs, return on investment, etc., are used to define the manager's goals and alternatives. In the examples just described, the choice of an accounting method becomes very important in view of the fact that alternative accounting systems will tend to produce different decisions.

4.3. Area for Further Research

Our analysis in the last section leaves unanswered the question of whether or not the choice of accounting methods will affect decisions as we consider the infinite number of possible environments between ill-structured and well-structured. We have not been able to specify the general environmental conditions to predict when a choice of accounting methods would (or would not) affect decisions.

To establish a description of these general conditions, we need to investigate many issues in addition to the ill-structuredness of the environment, such as (1) the extent to which good or poor timing of accounting data affects decision, (2) the degree to which different methods of presentation of accounting data affect decisions, and (3) the extent to which the reliability (or lack thereof) of an accounting process affects decisions. In this paper

[12] Smolinski (18, pp. 602–13).

[13] Note that many of the arguments in support of transfer pricing have been based on arguments about their psychological advantages or disadvantages. (See Hirshleifer (10) and Dean (5).) See also Ijiri (12), where the degree of the divergence between the organizational goal and the goals of its subsystem is analyzed by means of a "goal indicator chart" and a "goal indicator divergence coefficient."

[14] Granick (9, pp. 227–47).

we have begun to outline the variables that determine the effects of alternative accounting methods on management decisions. There is a need for extensive additional research both to find other important variables and to test empirically hypotheses already proposed.

5. Summary

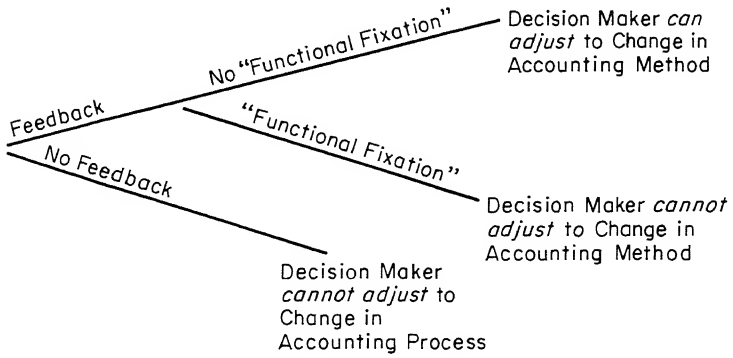
We now summarize our above analysis as follows:

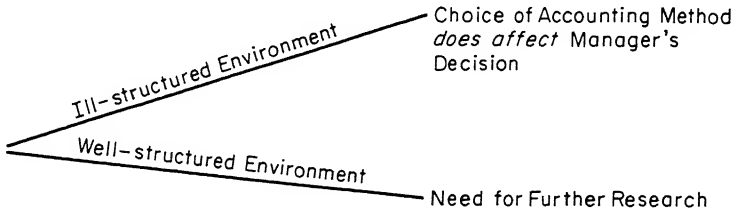
1. A decision process may be characterized by three factors: decision inputs, decision outputs, and a decision rule.
2. A surrogate may be used in place of a principal input if a surrogate is available at the time of the decision (timing) and if it is possible for the decision-maker to identify the key factors of the principal input which affect his decision (identifiability). The notion of a satisfactory surrogate is introduced in connection with the requirement of identifiability.
3. A decision-maker may need to use a surrogate (a) if it is difficult for him to obtain the principal input (cost consideration, time lag, etc.) or (b) if it is difficult for him to use the principal input due to the limit in his capacity to consider it in making his decision.
4. The two types of surrogates are: (a) a descriptive surrogate and (b) a predictive surrogate. A descriptive surrogate is one which is caused by a principal. A descriptive surrogate succeeds the principal timewise, such as in the case where the reported cost is used as a surrogate for the real cost.

 On the other hand, a predictive surrogate is one which causes the principal. A predictive surrogate precedes the principal timewise. An example is the use of the current cost as a predictive surrogate for the future cost.
5. The intimate relationship between the accounting process which produces a surrogate (y) from a principal (x) and the decision process which generates a decision (z) based upon a surrogate (y) is explained by means of a simple example,

$$x \xrightarrow{f} y \xrightarrow{g} z$$

6. Then, the question, "Under what condition can (or cannot) a decision-maker adjust his decision process to change in the accounting process?" is considered in terms of (a) lack of feedback and (b) functional fixation upon accounting concepts and measurements.
7. Finally, as an important case where the *choice* of accounting method does affect decisions, we considered the role of accounting processes in supplying operational goals and alternatives for a decision-maker who is confronted with an ill-structured environment.





6. Conclusion

We set out to explore the condition under which alternative accounting methods affect decisions. We did this by proposing a theoretical clarification of the mechanics by which the accounting process and the decision process are related. Of course, the relationship between the two processes is a complicated one. We do not claim, by any means, that all variables and their relationships involved in the problem are identified in the above analysis. We believe, however, that at least the *key factors* in the relationship between the accounting process and the decision process are clarified in our theoretical analysis.

Much research still needs to be done before we can make more precise statements concerning the relationship between the accounting process and the decision process and before we can state in precise terms the effects of accounting alternatives on management decisions.

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MANAGERIAL ACCEPTANCE OF SCIENTIFIC RECOMMENDATIONS

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There is evidence to show that managers may have perfect information available and yet not make correct decisions. The author rejects the idea that the missing link between information and decision making is analysis, through which managers transform available information into a knowledge of action. Improved modes of communication are also rejected as prime vehicles for gaining acceptance of scientific recommendations. Accepted as a missing ingredient in implementation is an understanding of the manager. It is pointed out that, by gaining an awareness of a manager's coalition, the researcher may learn more about how he decides where to direct his attention.

Those who have thought and written about management often refer to management "know-how" as an essential ingredient of success. By know-how they apparently mean the ability of the manager to understand what is going on in his environment. It is the chief concern of the management scientist to translate these vague stipulations about management knowledge into precise and verifiable assertions about how decisions are made and how decisions ought to be made.

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One of the central problems of management science is the understanding of the role of information in decision making. The reason this problem is so difficult is that we have failed to pay enough attention to the very subtle concept of the *use of information.* The much maligned classical economic man was supposed to act in accordance with his self-interest, given complete information. But what does *given* mean in this context? What the economist meant was that the information was automatically fed into the rational decision process, and the correct answer was

thereby derived. If the manager of a firm can be adequately represented as a computer, this concept of *given* may be adequate, for then we merely mean by *given information* the inputs to a computer program.

However, when we consider real managers in their real environments, the concept of given is not clear at all. Let us picture a manager busily at work making a number of decisions. Suppose by some lucky chance that sufficient information is "available" for him to make a perfect decision in each case. We need some operational definition of *available,* and the one that comes most readily to mind is that information is available if it is stored in the form of retrievable symbols in the environment of the manager. More precisely, a piece of information is available to a manager if he can retrieve it at virtually zero cost (e.g., by asking someone or looking it up or retrieving it from computer memory). Even this more precise meaning of *available* leaves much to be desired, but the definition will suffice for the purpose of stating the problem of this article, which is: There is sufficient evidence to show that a manager may have perfect information available to him and yet not make the correct decision. What is the explanation of this phenomenon? Why don't managers act on the information stored in their environments?

Before proceeding to discuss this problem in depth, something more needs to be said about the concept of a *right choice,* i.e., about knowledge of the correct action. A man may choose the right action by accident, so to speak, when in his clumsy way he stumbles upon the correct way to act. Thus, an archer who hits the bull's-eye does not necessarily know how to shoot. What makes the expert archer is the ability to adjust his method of controlling the arrow so that, no matter what the motion of his target, within limits he can perform successfully. Hence, knowledge about a decision consists of choosing the correct action even though the conditions change. Knowledge is a sensitivity to changes in one's environment.

Inventory Control

The point can be illustrated very well by referring to inventory control within industry. Most companies do reasonably well with their inventories during periods of stable demand. This is because the managers responsible for controlling inventory learn from experience that ordering too large or too small quantities is bad policy, and they have also learned to prepare for normal shifts in demand in terms of buffer stocks. But we would not say that the management has knowledge of the control of inventory unless it has developed a method of adjusting to large shifts in demand or in costs.

Hence, when an operations research team comes in and tries to develop models, it often finds that its recommendations do not deviate very far from the current practice of the management. This does not imply, however, that the work of the operations research team has been wasted. On the contrary, once a model is developed, the parameters of the model can be adjusted to take care of variations in the environment, such as the upswing or downswing of demand, the costs of carrying inventory, placing orders, or shortages. Thus, the great advantage of modeling industrial operations is that the manager is then in an excellent position to adjust for changes. In other words, according to the definition of *knowledge* introduced above, the manager is provided with awareness of the

right action rather than mere display of the right action.

The point cannot be overemphasized. Often in companies we find that men with years of experience have arrived at methods of managing operations which cannot be matched by analysis. For example, a vice-president of sales of a large company would forecast sales of the company's products based on reports received from the field, economic data, and other types of information, coupled with his own judgment. He seemed to have an uncanny way of coming up with accurate estimates that we could not duplicate by any statistical methods known to us. In this case the company could be said to have arrived at the correct action, but again I doubt if we would want to say that the company had knowledge of forecasting. If the vice-president were to leave, the environment would be changed, and the company would have no obvious way to adapt to the change. Thus, our statistical methods, though perhaps slightly inferior to those of the vice-president under current conditions, constituted something more like knowledge than the vice-president's intuitively based decisions.

A Matter of Ability

In the discussion above, it is clear that I have been describing knowledge as a matter of ability. It is the ability of a decision-maker to adjust his decisions to changes in the situations that confront him. We could go on to describe deeper forms of knowledge. For example, we might want to consider the way in which knowledge of decision-making in one area assists decision-making in another area or the way in which knowledge of decision-making can be refined, so that finer and finer distinctions can be made between types of decisions. I think these deliberations would lead us to a consideration of "understanding" as opposed to mere knowledge, because understanding is essentially the process by which the decision-maker knows why his method of decision-making is correct. To know "why" is to go beyond the present situation to a larger world, to understand why the decisions in the present situation are justified by considerations of the larger world. Essentially, understanding represents the highway from knowledge to wisdom; wisdom is the highest form of understanding.

Assuming that enough has been said about knowledge, let us return to the problem stated at the outset. We have pictured a man in an environment where sufficient information is available to provide him with knowledge of how to make decisions. Why doesn't knowledge occur?

One ready answer is that the information is too costly to obtain. Indeed, we have hidden in the definition of *available* the very difficult concept of *cost of information,* and we could devote many pages to discussing this concept as is done, for example, in the work of Radner and Marschak (7) on the theory of teams. Instead, in order to put the problem of this article into sharp relief, we will assume for the moment that we are talking about a manager who can retrieve information readily at no cost. Why does this manager fail to use the information so readily available to him?

Use of Information

The obvious answer is that he does not know how to transform the available information into a knowledge of action. In other words, he does not have a program built into his mind that will transform the inputs into

correct outputs. Thus, operations researchers have suggested to the manager the wisdom of using personnel who do know how to do just exactly this: They know how to take the information available and calculate a decision system which, in effect, provides the manager with the knowledge of how to behave. We generally refer to this type of activity as analysis. Hence, the suggestion is that the missing gap for many managers is the lack of someone or some device capable of performing the necessary analysis.

Unfortunately, we have overwhelming evidence that available information plus analysis does not lead to knowledge. A management science team can properly analyze a situation and present recommendations to the manager, but no change occurs. The situation is so familiar to those of us who try to practice management science that I hardly need to describe the cases. Some of my graduate students undertook to write to the authors of cases reported in *Operations Research* over the first six years of its publication to determine to what extent the recommendations of the studies had been carried out by management. In no case was there sufficient evidence that the recommendations had been accepted.

At the University of California, Professor Ratoosh and I have been conducting some experiments in which we have been able to establish in controlled situations that analysis plus available information does not lead to knowledge. In our experiments, five subjects run a small firm. The instructions given to the subjects provide complete available information about the firm's operations. That is, it is possible so to analyze the information that the managers of our laboratory firm can adopt the right action. Furthermore, by analysis it is possible to generate a model which will provide the managers with a method of making decisions, even though demands and costs and other factors change. In other words, the model can provide the managers with a knowledge of how to act. In some of our groups we have placed a person who has gone through the analysis beforehand. He is then given the task of persuading the rest of the management team. Therefore, in our laboratory we have constructed a situation in which there is available information plus analysis. The result has almost uniformly been one in which knowledge does not occur. The managers do not accept the recommendations and are far from gaining any knowledge from the analysis (8 and 9).

Of course, one could say that the difficulty is that the available information is in one location (the instructions given to the subjects), the analysis is in a second (in the head of one person), and the decision-making is in a third. One might feel that if all three of these components could be combined into one unit, the problem could be solved.

This suggestion is a reasonable one and brings us back to the original definition of available information for the purpose of revising it somewhat. The original definition made *available* a very passive kind of thing and ignored the very important concept of "transmittal of information." How is the information to be retrieved? If the channels of retrieval are obscured by linguistic ambiguities and other noises, the information may not be available, no matter how precisely it is stored.

Concept of Communication

The concept we seem to require is "communication." Communication is a device for taking several minds and making them act more like one mind.

Thus, many people have suggested that the missing variable in the equa-

tion is proper communication, that available information plus analysis plus communication leads to knowledge. They say that if only operations researchers could learn to talk in a language the managers can understand, there would be no further difficulties in implementing operations research recommendations. Thus, articles on the implementation of recommendations speak over and over again about the need for better communication between the scientist and the manager. These articles point to the fact that the scientist talks in a semiformal language (mathematics) and the manager talks in his own management terms, which are not exactly those of normal discourse. The problem, say these articles, is to make the proper translation.

Mode of Communication

Of course, to prove the invalidity of the new formula (information + analysis + communication leads to knowledge) is very difficult because there are so many modes of communication. However, in our experiments we have found no adequate mode. We have presented the solution in simple graphical form, in simple arithmetical form, in ordinary discourse, as well as in the form of more complicated mathematical expressions. We can find no evidence that the mode of communication makes any difference. We have presented the solution in pieces and in a total report, and, again, we have found no difference. I am aware of the fact that the sociological literature, and especially the work of Hovland (3 and 4), has dealt at length with the importance of mode of communication with respect to persuasion, but we have not been able to translate these findings into our own work.

Of course, I am not saying that the mode of communication has no effect whatsoever. It is not very difficult, even in our experiments, to prepare messages which are so incomprehensible that they have no effect whatsoever, except to annoy the managers. What I am saying is that the formula will not do. More precisely, the prescription for "better" communication ends up by being no more than a restatement of the problem: to find some set of activities so that with complete information available, the manager will come to know the correct action. It is the attempt to find such a set of activities that makes the problem very difficult because by now we have exhausted all the obvious possibilities.

The next suggestion is one with which I am sure most managers and scientists are familiar. One must bear in mind the distinction between the personal goals of the manager and the organizational goals. Even if the corporate goals are explicit and clear, the manager's own personal ambitions may be at variance at times with the interests of the corporation. Therefore, if the scientist generates a method of making decisions that best serves the corporate aims, he may encounter resistance because the recommendations do not fit into the manager's personal goals. In other words, it is possible that a manager who really wanted to accomplish the organizational goals would come to know the correct action.

For example, it is a well-known fact that managers feel threatened by modern techniques of analysis. They have reason to believe that analysis, with the help of high-speed computers, may take over their roles. In order to preserve their status, they resist the recommendations that analysis provides. At this point one usually distinguishes between a perceived threat and a real threat. The perceived threat is one that may be incorrect; for exam-

ple, it may happen that sophisticated analysis strengthens rather than weakens the manager's role. The task of the researcher in this case is one of clarifying the situation for the manager, though how this is to be done is often very obscure. A real threat is one that does, in fact, threaten the manager's role, making it either obsolete or less important.

Reaction to Change

A more general way to describe the problem is as follows. When a change is suggested to a manager, he reacts in ways that are typical to his own personality. Part of him will resist the suggestion, and often the resistance is so strong that he will reject the suggestion altogether. Nevertheless, the persons responsible for making the suggestion may learn enough about the manager's personality so that they know what to say to him to break down his resistance. Thus, they recognize that there is a part of the manager's personality that will adjust to change. On the other hand, there may be a part that remains invariant, no matter what the environment. Indeed, psychological literature leads us to believe that most men display invariant characteristics over most of their lives: They rarely change from an extrovert to an introvert or from a thinking type to a feeling type, for example.

These reflections imply that the missing ingredient in the process of implementation is the understanding of the manager. Any research team that fails to study the manager and his personality may very well fail to bring about a recommended change. Furthermore, any research team that believes it can implement a recommendation by the same process, regardless of who is managing, is simply naïve.

Because he often lacks a methodology of understanding people, the researcher may give up any attempt to implement broad changes of policy. Instead, he may be satisfied to work in areas where the status and role of the manager remain invariant no matter what is changed. A manager may not feel threatened if the equipment in his shop is redesigned or if physical sequences of actions are changed. But if someone asks whether his shop should manufacture the items it does, in the quantities it customarily makes, he cannot help but regard this question as one that is directed to his own role. If he is a reflective type, he may enjoy the question; if he is an anxious type, he may not. Even if he enjoys the question, he may believe that a solution arrived at by analysis stifles his imagination. His personality may be such that he must act instinctively and creatively or not act at all.

Coalitions in Management

Perhaps the most important invariances of personality occur in the formation of coalitions in organizations. These are the so-called political aspects of management in firms. A coalition may arise because the members of the coalition recognize certain common economic advantages. But it is well known that coalitions also come about because of the personalities of their members; some mix of attitude, trait, and opinion creates a loyalty that is hard to dissolve. The loyalty is strengthened by opposition. Thus, various obscure and complicated coalition frameworks occur among managers; they are obscure because no one ever writes down their bylaws and articles of confederation or ever announces them publicly. Indeed, most managers are not clearly aware of them. For a further discussion of this point, see Cyert and March (2).

These coalitions of managers are like the "invisible colleges" of scientists; see, for example, Derek Price (6). They are the sources the manager consults; they are the basis of the language he uses; they provide the criteria of what is important and what is unimportant. They are made up of persons, books, journals, and other communication devices in the manager's environment.

Thus, in the context of managerial politics, the researcher is apt to find that his recommendations are viewed from the point of view of their effect on a coalition and not from the point of view of the whole organization. Since the researcher usually doesn't know who belongs to what coalition, and is far from understanding what holds the coalition together, he cannot determine how to overcome coalition biases. He finds himself in a confusing welter of contradictory reactions of managers.

A Scarce Commodity

The most significant outputs of the hidden managerial coalition are the importance of issues and the ways in which important issues should be considered. Managers control a very scarce commodity: their own time and attention. Their most conscious problem is one of determining to what they should pay attention. A researcher who claims he can save them a few thousands or millions of dollars may immediately lose their attention, because the managers believe that a new market or a threat to the corporation's existence are far more demanding of their attention than cost savings, especially if the method of analysis is alien to them.

In other words, one aspect of the formula suggested earlier was quite faulty. It may be true that information + analysis ideally leads to knowledge, but analysis takes up a significant portion of the manager's time and energy. One measure of the cost of analysis for him is the distance of the analytic method from his typical way of thinking about problems. His typical way of thinking comes from his coalition. A very striking example of a manager's reaction to "scientism," i.e., alien thinking, is to be found in a recent article by Lilienthal (5).

Thus, to discover what a manager thinks is important and how he believes he should think about important issues, one must determine to whom he listens; and to determine to whom he listens, one must understand the coalitions to which he belongs. Some of these coalitions are external to the company; they are the other members of the managerial community whom the manager respects. These large coalitions of managers in specific industries account for the managerial styles and fads. If these coalitions come to believe that science and especially mathematics and computers are important, managers will pay attention to scientists. If not, they won't pay attention, no matter how elegant the recommendations the scientists make.

Problem of Attention

I have purposefully been vague about the meaning of a coalition, in order to emphasize a point. But the definition is really quite simple: A manager's coalition is the group of people who influence what the manager attends to. I do not say that they are the group that influences what he does, because this is too narrow a concept. The manager of a competing firm may hire an operations research group. If this influences another manager to learn about operations research, the first manager belongs to the second's coalition.

There is little doubt that, in the

experiments we have run at the University of California at Berkeley, the problem is one of attention. The subjects quickly form one or more coalitions and then become much too busy to want to attend to the recommendations that are made to them, even though these recommendations are correct. The analysis offered may be foreign to the way in which they have taught themselves to think about their task. In some mysterious way, the subjects agree that the way they are organized, "not going into the red," and various other secondary aspects of the task are the most important.

If we are to learn more about the implementation of recommendations, we must learn more about how people decide where to direct their attention. It is for this reason that at Systems Development Corporation, Herbert Eisenberg, Martin Shubik, and I have started a few very simple experiments on deliberation and its role in decision-making. Deliberation is the process by which the mind in reaching a decision scans various aspects of the problem. In our experiments, we present one subject with alternative points of view to which he may pay attention, and other subjects try to influence him towards one viewpoint or another. We are attempting to learn more about the way in which managers come to pay attention to issues.

This essay is a mystery novel, with the added frustration that the culprit remains unidentified even at the end. Perhaps the advantage of such a devilish novel is that it may suggest a better plot for the next one to be written. With this in mind, let me end by introducing some broad philosophical generalities, not supported by the available evidence but nonetheless helpful in future research.

We started by looking for the ingredients that a research staff would seek to supply in order to bring about a recommended change: available information, analysis, and communication. We argued in the end that none of these ingredients matters at all unless the manager pays attention to the problem and that paying attention is an obscure process of the managerial mind, little understood by management scientists.

An Obscure Concept

The obscurity we face in this regard is simply the obscurity of the concept of decision-making itself. We do not yet understand how to describe a human decision. The descriptions usually offered reflect the psychological traits of the describers. A thinking type believes that the mathematical theories of games and of optimization will provide all the concepts necessary to define a decision clearly, as well as a correct decision. He is arrogant enough to label his efforts *decision theory,* without any uneasy pang of conscience. The feeling type asserts that a decision is essentially a unique expression of human values and that the meaning of a decision cannot be captured by generalized mathematical expressions. An intuitive type believes that decisions are insights, quick flashes of understanding how to solve a problem. They frequently assert that the manager leaps to his conclusion without benefit of, or even need for, analysis. Finally, there are those who assume that the whole business of decision-making is contained in available information: What decision is made depends solely on what facts are known.

A Manager's World

Philosophy attempts to take one step back from the issues that divide sci-

entists into intellectual camps. All the points of view mentioned above are valid. They amount to saying that decision-making can be conceptualized in many ways. What seems to be common to these ways of describing decisions is the concept of focus (1). A specific decision is the focus of a mathematical model, of a general value structure, of insightful behavior, of masses of data. The focusing that leads to decision-making takes the manager's whole world and displays a subarea where he must seek a solution. Within this subarea the coalitions that influence this behavior lead him to confine his attention to certain aspects. Eventually, he is led to one alternative, to the choice.

The rational mind of the scientist would like to remove all irrationality from this focusing of attention of the manager. The trouble is that, in order to do this, we scientists must understand the world of the manager—not a piece of it but the whole world. If we only understand a piece of the manager's world, we have no justification for asserting that he should pay attention to the piece that we present to him.

Thus, in order to recommend important changes to a manager, we must understand the process by which this whole world becomes focused on certain issues and aspects of his environment. Any decision is a snapshot of the universe of the manager. An optimal decision is a snapshot of a rational universe.

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Editorial Comment for Chapter 10

Caplan presents an interesting comparison between behavioral assumptions of the "traditional" management accounting model of the firm and those based upon modern organization theory. The merits of these theoretical models must ultimately be judged by the relative usefulness of the information systems that logically derive from them. In an article written later Caplan suggests a three-step field investigation:

1. The investigation of a sufficient sample of management accountants to permit the identification and comparison of examples of each of the models of behavior as well as various intermediate stages between the two extremes.
2. An analysis and comparison of the behavioral assumptions which underlie each of the models studied in an effort to determine the relationships between the various assumptions and the models which result.
3. An examination of the consequences for the organization (and for the participants) of each of the behavioral models studied. This examination would involve (a) a study of the conduct of accountants which is associated with each model and (b) an investigation of the effects of this conduct on the organization and its participants.[1]

Ijiri, Jaedicke, and Knight (IJK), like Caplan, draw upon concepts from modern organization theory. IJK present a useful theoretical framework for examining the relationship of accounting information and decision processes in the firm. The conclusion that changes in accounting "will not affect decisions if there is feedback on the performance of the accounting system and if there is no functional fixation" should be of great interest to information systems designers. If future empirical studies support this contention, one may well be tempted to predict increased permissiveness in the choice of measurements for management reporting. It is important, however, to point out that, while these observations may apply to operating-level decisions, a somewhat different analysis obtains for strategic decisions made in an ill-structured environment.

Stressing the work of Cyert and March, IJK state that when people are confronted with an ill-structured decision situation, they will attempt to define, structure, and simplify the situation. Simplification is achieved "by using surrogates

[1] Edwin H. Caplan, "Behavioral Assumptions of Management Accounting—Report of a Field Study," *The Accounting Review,* XLIII (April, 1968), 342–43.

which are aggregates of a number of principals or by neglecting some of the principals." The dominance of a single criterion, such as reported profit or return on investment, in performance evaluation systems can perhaps be explained by peoples' inclination to avoid uncertainty. Using "standard operating procedures" is another basic means of arranging the environment and preventing uncertainty.

The IJK reading is essentially an attempt to frame a descriptive, as distinguished from a normative, theory of information-decision processes. The normative implications for information systems design remain unclear. This is partly because the role of the information analyst in organizations, particularly as it relates to the executive policy-making function, is often ambiguous. If the information analyst were to use descriptive behavioral theories such as that offered by IJK as a basis for designing management information systems, he might be accused of "managing" the behavior of decision makers. On the other hand, there is the serious question of whether management can objectively and competently use behavioral theories that focus on *its* behavior to design effective, efficient information systems. A partial solution to this dilemma is likely to be found as the tasks of information design and decision making become better integrated in organizations. As decision makers become increasingly analytical, they presumably will be able to dictate more precisely the content, format, and timing of their information requirements.

Churchman is also concerned with understanding the role of information in decision making. Specifically, he addresses himself to the question of why managers fail to use readily available information, particularly scientific recommendations. Neither well-conceived analysis nor improved modes of communication necessarily lead to the adoption of recommendations, according to Churchman. Recognizing that the personal goals of managers may differ from those of organizations and that managers react differently to proposed change, he argues that the key to the implementation of recommendations is an understanding of the manager. Once again, this raises the question of the appropriate role of the management scientist or information analyst in the organization.

Churchman's adaptation of Cyert and March's coalition concept poses some significant questions about current styles and trends in information systems. At the present state of the art, integrated systems that incorporate the point of view of the whole organization are almost universally idealized, though rarely achieved. Ironically, a logical implication of the Churchman reading is that a prime criterion for information is its relevance to the manager's coalition rather than to organizational goals. That is, to gain the manager's attention the information system must, in a significant fashion, reflect his way of thinking about problems. Here we see in bold relief the potential conflict between the total systems view of management information and the aims of implementation.[2]

[2] For other studies related to management acceptance of scientific recommendations, see Samuel G. Trull, "Some Factors Involved in Determining Total Decision Success," *Management Science,* XII (February, 1966); and Albert H. Rubenstein, *et al.,* "Some Organizational Factors Related to the Effectiveness of Management Science Groups in Industry," *Management Science,* XIII (April, 1967).

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